ENGINEERING WORK

IN

TOWNS AND CITIES

BY

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THIS BOOK

IS

AFFECTIONATELY DEDICATED

TO

MY PARENTS

PREFACE TO THE SECOND EDITION.

The publishers say a preface is necessary; otherwise this would not have been written, for the first chapter is essentially an extended preface.

In 1893 a report was made to the Trustees of a small town in California, on matters pertaining to municipal improvements, by the author, who then held the dual position of Town Engineer and Street Superintendent, incidentally serving also as Engineer for the local Board of Health. Titles were cheaper than fees and the average Councilman thinks titles have a charm for engineers. In 1894 the articles were collected in pamphlet form under the name of "Public Works, A Treatise on Subjects of Interest to Municipal Officials." The book was nicely received and some of the reviews were almost a reprint; not a difficult thing in view of the few pages it contained.

In 1900 it was entirely re-written and the number of pages multiplied by three. This second edition also had a flattering sale. As the first had been purchased largely by engineers, the second edition was more of an engineer's book and the title was modestly changed to read "Municipal Public Works, An Elementary Manual of Municipal Engineering." That title might have been retained had not Mr. Whinery in 1903 brought out his book, "Municipal Public Works," intended solely for the non-technical reader.

In 1906 the first edition of the present book appeared. It was essentially the pamphlet of fifteen years ago; the same book grown up. It aimed to fill a want experienced by all engineers on first taking up the duties of city or town engineer. So far as the author could ascertain, there was then no book to be had covering the ground. How well it met the need has seemingly been evidenced by the number of appreciative letters received by the author. It has made him grateful and humble. It has also fired his ambition to do better some day.

The first edition of "Engineering Work in Towns and Cities" was really two books. Each subject was treated in separate chap-

ters in a manner intended to be of interest to non-technical readers. In the last part of the book the same subjects were treated technically in the same order. Thus it was possible for engineers and their official superiors to get enjoyment and profit from the same work.

In this present edition the arrangement has been changed so that each subject is practically complete for all classes of readers in the chapter devoted to it. Errors where found have been corrected. Some new matter has been added and the section on Reinforced Concrete has been entirely re-written. The Index has also been carefully prepared as befits a work intended to be a hand book.

To the younger members of the profession the author would commend a careful study of the following sage remark of Bacon, which has always held a charm for him hard to express:

"I hold every man a debtor to his profession; from the which, as men of course do seek to receive countenance and profit, so ought they of duty to endeavor themselves by way of amends to be a help and ornament thereof."

THE AUTHOR.

Chicago, Ill., Sept. 15, 1908.

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CHAPTER I.

THE CITY ENGINEER AND HIS DUTIES.

This book is written for two classes of officials in towns and cities having a population of less than twenty thousand inhabitants and it may be found useful in some larger places.

Elected officials and those who have had no technical education belong to the first class. They come into intimate relations with men who have charge of engineering work, are interested in it, oftentimes direct it and therefore may be benefited by reading this book.

The second class is composed of engineers and surveyors holding the position of town or city engineer. Especially those with little or no previous experience in municipal engineering.

To meet the requirements of the two classes the book has been divided. Both will appreciate the chapters preceding those on office work. The chapter on bibliography and that on the filing of fragmentary literature will likewise interest both. So, it is believed, will the appendices.

The chapters on field and office work and engineering data are intended solely for engineers. The non-technical reader will hardly appreciate them.

It is hoped the plan will be successful. In larger cities engineers have other sources of information and this book will hardly interest them. The writer hopes that for places having less than ten thousand inhabitants this book will be a satisfactory manual of municipal engineering.

The sources of information available to men in larger cities and which it is hoped every engineer will at some time or other consult, are given in the chapter on bibliography. The books and periodicals there mentioned have all been freely drawn upon by the author who takes this means of acknowledging the assistance

he has received. To make a separate acknowledgment in each case would require too many small type notes. The publishers do not like the expense, the printers hate them and readers cordially detest them. Besides, so much of the information is common knowledge it would be difficult and will nigh impossible to know whom to credit. In a few cases acknowledgment has been made.

Not all the matter, however, is reprint. Much of it is the accumulation of many years' experience in this kind of work. It is believed some is here printed for the first time, as it has been picked up in the field, over the drawing board, at engineers' conventions, and in conversation with experienced and practical men. Perhaps it has all been printed before. If so it is in widely scattered publications and therefore not accessible to the majority of engineers. The author is not claiming originality for all that appears in these pages. He simply has tried to put in convenient form some odds and ends of professional knowledge which may be appreciated by the men whom it will benefit.

It may be inferred from the residence of the writer that the work is simply compiled and that his knowledge of conditions in small towns is second hand. For over five years he served as town engineer, street superintendent and member of the Board of Health in a far western city of less than two thousand inhabitants. For two years he served as city engineer, street commissioner and building inspector in another western city of nearly three thousand inhabitants. In the West (the real West of today) a place of two thousand can be compared with places of six thousand in the eastern States, and a place of three thousand with one of eight to twelve thousand in the East, so far as the class, character and amount of work is concerned. In his consulting and contracting experience the writer has had much to do with towns and cities ranging from five hundred inhabitants to many thousands. This book, therefore, does not contain simply impressions of an engineer from a large city. When he tells how to drain a street he does it because he has been out in rubber coat and boots in storms showing "dagos" how to take care of the water. When he tells how to stake out work it is a description of methods he has used and found good.

Such an introduction the author feels is due his readers. Today there are many books compiled in libraries by men of little

experience. Readers are clamoring for something "practical," and as this book is intended for men who pride themselves on being practical they should know they are getting first hand information—supplemented, of course, with selected matter from good authorities.

The book hinges about engineering work and therefore about the engineer. For the average engineer employed by the average town and small city the author would like to make a plea.

Three classes of men are engaged for such work and receive appointments by the council. The first consists of men who are not engineers. They are surveyors and sometimes of the kind called "land butchers." Their work is of a kind not calling for the refinement and niceties of city work and they are apt to be careless and good humored over mistakes. City surveying requires measuring with steel tapes and turning angles on tack points. A "row of apple trees" is too vague a limit of accuracy for city work. As the pay of surveyors seldom approximates that of engineers, surveyors will take the position of town or city surveyor, or engineer, at a much lower salary than an engineer will accept. If the surveyor is a bright man who will work hard and study hard he may develop into a good enough man for the place. Such men, however, do not always develop that way.

The second class consists of men who principally follow surveying for a living but are anxious to become engineers. They have no technical school education but are largely self educated and have received some earlier training on railroads, or with large corporations. If appointed town or city engineer before their ambition weakens they develop into first-class men. It is becoming increasingly difficult for an engineer without a technical school education to succeed. In a specialty, however, a self-taught man has an excellent chance. Some of the finest engineers the writer has met in small places are of this class. Their work is their hobby and they read and study all the time and put into practice as much as they can. A town possessing a man like this should keep him.

The third class consists of men educated at good technical schools. They may have considerable experience before accepting the position, or they may not. Their training, however, teaches them how and where to acquire needed information and if con-

tent to remain in the small place and grow up with it the town will be the gainer by keeping such a man as long as he is content. As he is well educated and up to date he must be paid properly and treated with consideration to keep him contented while his classmates are winning success in larger fields.

While the engineers honored with appointments as engineers in the small places have been above graded by their educational opportunities and natural inclinations toward study they can, in each grade, be classified like all men into ranks ranging from very wise men down to something a degree worse than a plain fool. But if occasionally a town picks up one of the latter the whole profession should not be judged by him.

It is assumed the councilmen will realize the importance of having a good man in the position and make careful selection. Unfortunately this is not always the case. It is usually customary to fix the pay a little lower even than a second rate "land butcher" would take and then hunt for an engineer to accept it. That men can be found to accept such pay and the treatment so often associated with poor pay, should not militate against engineers in general, but it does.

One important fact seems to be forgotten. The engineer is in this line of work to stay. It is his means of livelihood. If given the least encouragement he will apply himself to study and research and as the years go by his value can not be estimated. His death or removal will be little short of a public calamity.

The councilman on the other hand is elected for a short term. He may, or may not, be re-elected. After he returns to private life he loses interest in the engineering work and after awhile forgets all he ever learned in his brief tempestuous term as a city father. Under such circumstances his interest in the best good for the people who elected him should lead him to be careful in selecting the engineer. When he does select a good one he should treat him at least as considerately as he does the town attorney, whose word is law—and occasionally poor law.

The attitude of the average councilman toward the average engineer was shown when a national organization of public works officials was started a few years ago. One elected official fought against admitting engineers to membership. "They are our servants," he said, "and we do not want them arguing with us in

open meetings." His position was supported by many, but the engineers won out and were admitted. Today the membership is almost entirely of engineers. The elected officials are such a short time in the work that they do not feel like joining the society.

An English councilman said: "Our surveyor is a man with very big ideas; he is always bringing forward some large scheme just as though he must do it to justify his occupation here." (Goodrich, "Disposal of Town's Refuse.")

The remark has a pathetic ring to it. The town had an energetic and ambitious man who rushed with enthusiasm into his work and was checked by the complacent and tolerant air of his superior officers.

There is another side to this. An engineer is seldom tactful. So much of his work can be approached in a direct manner he is apt to be impatient when questions of policy come up. There are two ways of getting results in mathematical operations. The only proper way is to figure correctly and the result proves itself. Sometimes an engineer has been known to make a result come to where it should by a process known as "fudging." That is, he starts from the answer and with the assumed, or actual, conditions works to it by short cuts and empirical rules to save time and trouble. While the same result, or at least a satisfactory result, may be obtained, it is not workmanlike. It is therefore in the code to do everything right and in the most direct and accurate manner possible.

The city father, on the other hand, has to answer to his constituents and must evade objections of men in the council whose constituents represent interests opposed to his own. Policy must govern nearly all he does. He has to plan ahead and can often see a point the engineer fails to see. Policy forbids him taking the engineer into his confidence. To a man who has some interest to forward and who is unable to pursue direct methods it is the extreme of exasperation to run up against a "rule of three idiot," as the writer heard a young engineer designated in one place where he was called into consultation.

Therefore it is that many councilmen in the smaller places wish as an engineer a man who will really be the surveyor to the council. His duty is to set stakes where ordered, in the manner ordered and not until ordered. If they can get such a man they

take delight in ordering him around and they disparage all engineers because of the example in their own place.

When a real engineer is placed in such a position there is a great deal of unnecessary friction. In addition to this the average property owner seldom likes an engineer. He is considered to be an unnecessary expense and it has been seriously proposed in many places to drop engineers altogether and let contracts to men who will set their own stakes and work on honor. The places that have tried it never seemed satisfied.

Why employ an engineer? Engineering News once said, "The fact that a competent engineer can make a little money go much farther than it would go without his advice and aid is one which the general public is slow to comprehend. The average man congratulates himself upon the dollars he saves by dispensing with an engineer's services and knows nothing of the dollars lost in exorbitant prices or in work poorly executed."

Boswell says, "The true, strong and sound mind is the mind that can embrace equally great things and small." The giving in once in a while to the opinion of a competent engineer is one of the small things that will really be a great thing for the city in after years. To have things started well is half the work. A cheap, incompetent man means untold expense in the future. A good man may mean that the city will always have pride in its appearance and in the character, with resulting economy, of its public work.

"Before a man can speak on any subject it is necessary to be acquainted with it," says Locke. A councilman can hardly get a thorough knowledge of municipal engineering between the date of his nomination and election so it is hardly seemly for him to give too full instructions to the engineer. If the engineer is not competent then the councilmen appointing him fail in their duty to the people whose affairs they administer.

Use care in selecting the engineer. Pay him as much as the town can afford and do not pay less than the rates current for such work in the vicinity. Deal with him as if he knew his business. If he shows himself incompetent fire him. If intelligent but merely lacking in tact let some one finish his education in policy. The policy of the councilman looks oftentimes to the engineer like "fudging." If he can be shown that it is simply

another process for attaining a right end and is not wrong he will be all right. An engineer is a creature of mathematics and common sense. If he is strong on mathematics and shy on common sense he is a poor engineer. But he must have enough mathematics to get correct results.

Much of the trouble—and the writer has found no place free from it—comes from an indefinite understanding of the duties of the engineer. The following ordinance is recommended as being now in satisfactory use:

ORDINANCE NO......

An Ordinance Creating the Position of City Engineer and Defining his Duties and Fixing the Compensation of Himself and Assistants.

The Common Council of ...... does ordain as follows:

Section 1.—That the position of City Engineer is hereby created in the ...., who shall be appointed on .... of each year and hold office for one year from the date of his appointment, or until his successor is appointed and qualifies, unless he is sooner removed for cause or by reason of abolishment of the office by ordinance.

Section 2.—He shall be a Civil Engineer of not less than five years' practical experience as such, and if a graduate of the State University, or of some technical school of equal grade, in the civil engineering course, his course of study shall count as two years' practical experience. A Land Surveyor of not less than five years' practical experience as such, but with less than two years' experience in engineering surveys and construction work, shall be eligible for appointment provided he graduates in municipal engineering from a correspondence school.

Section 3.—The City Engineer shall make all the surveys, maps, profiles, estimates of cost for improvements, and plans for public improvements ordered by the City Council, set all grade and line stakes for such work, supervise the repairs on streets, the repairs and cleaning of sewers, prepare all specifications for public work when so ordered, see that the building and plumbing ordinances and regulations are enforced and generally do all work that may be required by the Council of a civil engineer in connection with public improvements.

Section 4.—He shall preserve monuments and bench marks and establish new ones when necessary, upon orders from the Council, properly describing and recording the descriptions in record books and on plats.

Section 5.—He shall make suitable records in books and on plats, said records to be so complete that any competent engineer can from them and by their means retrace and check all work done by him. Said records to be and remain the property of the city and be turned over to his successor in office and a certified list of same be given to the City Clerk at the same time. Before any bills for work done by the City Engineer will be allowed the City Clerk must certify that the proper entries have been made in the record book for said work.

Section 6.—He shall prepare all ordinances that require phraseology of a technical nature for the doing of work under his direction or to describe work done and give same to the City Attorney to put into legal form.

Section 7.—The compensation of the City Engineer shall be .... He shall furnish his own office and all instruments, tapes and tools required and pay for repairs on same. The city shall pay for all papers, books and stationery actually used by him upon the city work.

Section 8.—He shall be free to select his own assistants and shall be held responsible for their work. No assistants can be appointed without an order from the Council and the compensation shall be fixed in said order.

Section 9.—Nothing in this ordinance shall operate to interfere with, or abridge, the right of the city to employ designing and consulting engineers and architects for special work or to advise with the City Engineer and supervise work he is in charge of, whenever the Council deems it for the best interests of the city to employ said specialists in certain classes or kinds of work.

Section 10.—This ordinance shall take effect and be in force on and after ....

It may be taken for granted that a consulting engineer will be needed occasionally. Sometimes the city engineer asks for one. This seldom happens, however, for a confession of incom-

petency is often thought to be implied when an engineer makes such a request. Why this is so is one of the things no man can explain. It is common for physicians and surgeons to call in specialists for consultation. No important case goes into court without an imposing array of counsel. The engineer, alone, is discredited if he asks for the advice of a more experienced man at the expense of his employers. No objection is made if he pays the bill out of his own pocket.

When selecting an engineer for special work the city engineer is generally able to recommend a man. It is assumed here that if the city engineer is worth his salt he will be a member of some of the local, or state, or national engineering societies and be a subscriber to one or more of the good technical papers or magazines. He will then be in a position to know the names and standing of the leading specialists.

Avoid selecting men employed by large corporations having interests in the vicinity, even if they do the work cheaply, or donate their services.

It is not always wise to employ a man representing patented or special articles. An unbiased man may recommend those very things, but it is better so than to have a man do it who is financially interested.

Some men may object that the foregoing ordinance gives too much to one man. Every man of common sense knows that few towns pay a street commissioner enough to live on; hence he must neglect the public work while he makes enough on the side to support his family. In many small places he owns teams and numerous relations are carried on the pay roll as drivers of the teams. The small pay never attracts good men and none of them know anything more about the street work than they pick up by themselves. Reading a book or paper to learn what others have done never enters their mind.

The fees of the building and plumbing inspector seldom amount to as much as a good man can earn by working for wages so good men seldom fill the position and the inspection is a farce.

Sewers are never cleaned. When plugged the obstruction is moved. That is all. The cost in the aggregate is high.

There is seldom enough surveying to pay a good man to give the records much attention. In fact it is often a loss for a man

to hold the position, but he takes it to prevent too severe competition.

The positions can all be combined and held by one good man, whose heart will be in his work; for the city can pay one good salary that will be less than the aggregate of several small ones paid to men who do not earn them. The engineer will then have some incentive to make a record and win the respect of the people.

CHAPTER II.

ROADS AND STREETS.

There are no set rules to follow in establishing grades and improving streets. The streets are to look well, are to serve as avenues of travel and are spaces in which the public may lay drains and conduits. They are to be improved at the lowest possible cost to attain these ends. All other considerations are matters of detail. In the work of improving streets experience counts for much and a knowledge of what others have done is helpful.

When grade is mentioned it is generally the longitudinal slope that is meant. By slope is generally meant the fall of the sidewalk or roadway toward the gutters. When cross section is mentioned it means the shape of the street from property line to property line.

Business streets should have, if possible, a level cross section, or one nearly level. That is, the curbs on each side should have the same elevation on a line across the street making a right angle with the street line. It is generally easy to accomplish this as the business portion of a town is, as a rule, laid out in the first place in the most level part of a tract of land.

To effect proper drainage the sidewalks slope toward the gutters and the roadway is high in the center to shed water to the gutters. The shaping and crowning of the roadway depends upon the width of the street and the material used for paving, as some smooth, impervious pavements require very little crowning. When one side of a street is slightly higher than another considerable study must be given it to secure the proper crown.

For a sidling street some men have the crown nearest the high side. Sometimes they make a straight slope across the street. This, however, is objectionable, as all the water has to pass over the street and may injure the pavement. The writer prefers to have the

crown somewhat to one side, for the slope is then exactly the same to each gutter, simply being longer on the lower side.

An old rule, and one in general use, for light grades is to make the crown on macadamized roads one-fortieth of the distance between curbs. For asphalt one-fiftieth, and for brick, stone and wood one-sixtieth. The reason asphalt has the greater crown is that water injures it and should therefore be taken off quickly.

Some towns are laid out on a hillside with contour roads and streets. Methods for improving them vary considerably, being influenced by the difference in elevation of the sides of the thoroughfares. When the difference is slight the curbs may be set at different elevations. When somewhat greater the sidewalks can be made narrow with a terrace to the curb. A still greater difference will permit of a terrace between the sidewalk and curb and one between the sidewalk and the property line. A greater difference may call for a sidewalk level with the curb and a straight slope from it to the property line. A still greater difference will call for only one narrow sidewalk on the lower side of the roadway.

In improving contour streets on hillsides an attempt should be made to get the improvement at the lowest possible cost consistent with appearance. The roads should wind and the slopes should be sodded as though in a park. Considerable swing should be made to go around trees rather than cut them down.

Business streets are improved from property line to property line. A common rule is to put two-fifths of the width in sidewalks and have three-fifths between curbs. Like all rules it is not to be blindly followed. A wide sidewalk is a good thing and a very wide roadway costs more for repairs than it is apt to be worth.

A wagon seldom occupies more than nine feet in width. Eight feet is the ordinary over all width. Eighteen feet between curbs will permit two wagons to pass with ease. Twenty-seven feet allows one wagon to stand at one side and permits two to pass it. Thirty-six feet will allow a wagon at each curb while two pass between them. It is seldom therefore that a business street needs to be more than thirty-six feet wide between curbs. As repairs are computed by the square foot it is well to consider that street repairs are expensive and sidewalk repairs are low. For a single street car track allow ten feet and for a double track allow eighteen feet additional to above widths.

It is a common matter today for small cities and towns to have in residence districts a roadway not exceeding twenty-five feet wide in the middle of the street. Each side has a curb and the ground slopes up from the curb to the property line. The sidewalk on each side is six feet wide and set one foot from the fence. For a sixty-foot street this gives thirteen feet on each side between the curb and sidewalk on which to plant trees and grass. Such a street is said to be parked. Great Falls, Mont., is a good example of a city so improved. Mr. C. W. Swearingen, for ten or twelve years city engineer there (now in Havre), had hard work to introduce such parking. Now the people are proud of their parked streets. In the writer's opinion it is the best method for residence streets. It is low in first cost and in cost of maintenance. It is beautiful in appearance. It also affords space in which to put sewers, water pipes, and underground conduits on each side without tearing up the street surface.

Sometimes a town has streets with very steep grades. The writer in 1893 prepared plans for the improvement of a street having a 21 per cent grade (a rise of twenty-one feet in one hundred), by winding a sixteen-foot roadway from side to side. The roadway had a grade of only 11 per cent and there were many slopes to plant with grass and flowers. A narrow sidewalk was placed on either side with steps at the turns in the road. In Burlington, Iowa, there is such a roadway and within the past year Wm. Barclay Parsons of New York proposed the same treatment for some of the steep streets in San Francisco. In some European cities steep streets have been treated in such a manner.

In establishing grades two things are to be considered—drainage and traction. Any slope will cause water to move, but for macadam roads a minimum grade of one foot in two hundred is advisable. For pavements the roadway may be level from one end of the block to the other, but it should not be level if any grade can be obtained. For streets having a very light grade or no grade, a slope for surface water is obtained in the gutter by making what is known as a summit somewhere in the block. With a level street it will be in the middle. At the summit the bottom of the gutter may be at nearly the same elevation as the curb. At the ends of the block or at the catch basins the curb may stand a foot above the bottom of the gutter.

It having been shown that water can run off a level street, it is necessary to see the limiting effect of traction. Street grades should be limited between the lightest possible for efficient drainage and the steepest a horse can ascend with ease. The steepest grade should not exceed, if possible, a seven-foot rise in one hundred feet. Heavier grades, as well as extremely light ones, should be adopted only after most careful study.

Calling the load a horse will pull on a level surface 100, then on a grade of—

1	in	100	a horse will pull	90	per	cent.
2	"		"	81	"	
4	"		"	52	"	
5	"		"	40	"	
10	"		"	25	"	

The above table shows that the steepest grade on a street regulates the loads that can be hauled over that street. In many cities located on rivers the grades on the bridge approaches determine the wagon loads throughout the whole business district.

In the establishment of grades no block can be dealt with alone. It is necessary to study a district in order that the effects of the grade on one block may not be harmful. In the chapter on surveys a method is discussed for engineers, but a reference here may do no harm. Briefly, it is best to study the ground carefully and determine the streets designed to carry the main drainage. These streets having been determined, take up the entering streets one after another and see what grades can be fixed on them so the drainage plan will work freely. The street it is intended to improve may be among the last streets studied. The writer has known of cities going to an expense of many hundreds of thousands of dollars because such a study was not made in the beginning. Whenever a petition came in the engineer was instructed to set grade stakes for one block at a time and take into consideration only the conditions in that block.

Sometimes a town is so located that grades can be established one block at a time. This is rare, however, and a careful study is best. Such work is, of course, somewhat expensive, but once done it is done for all time and the records, if kept, will be serviceable. Avoid a "penny wise and pound foolish" policy in such matters. Future growth must be considered.

In establishing grades, the question of the expense of improving the street to the grade must be taken into account. This has to be figured as all other business matters are figured. When several possible grades are under consideration the best grade may be the most expensive in first cost if the street is an important business street. If it is a side street, or cross street, or unimportant residence street, the property owners should have a voice in the matter and be permitted to exercise considerable influence. Here the first cost will generally be the controlling factor. If any street, however, is apt to be an important line of communication or drainage, the question of first cost may be dismissed. The best grade is the one to obtain.

It is to be borne in mind that in mentioning grades the writer means the official elevations at controlling points on the streets and the slopes connecting the official elevations. He does not mean the actual earth moving and such improvements.

There is nothing in all the work of a municipal officer which requires more pure grit and courage than the work of establishing a grade preliminary to the improvement of a street. No matter how it is finally settled, he meets with the approval of a very few and makes enemies of many. Some of the enemies are vindictive and never let up. Until a regular grade is established each man has regarded the street in front of his own lot as so much of his own property and it is hard to persuade him that any one else has jurisdiction over it. He has sidewalked, drained and paved (?) it to suit himself, and, whether above or below the general level, is confident that his floor line is exactly where the grade should be.

Whatever the procedure adopted for gradually bettering the condition of the streets, the first step is to provide for proper drainage. A dirt road can give fairly good satisfaction if it is rounded up in the center and kept well rolled and has gutters on each side to conduct surface water to a place where it can be disposed of. Therefore, temporary grades can be established and gutters made. Sidewalks can be built on these grades.

The appearance of the streets have as much to do with the growth or failure of a city as any other thing. Strangers get their first impression of a place from the streets and nothing can be said in praise of the wealth or enterprise of the inhabitants, or of the

logical advantages of the business location of a city that will counteract the effect of a poor street as a first impression.

First impressions are said to be most lasting, therefore the streets should be attended to first. The questions of sewerage and water supply can be left until the city has at least one good looking street. Better sewerage facilities and improved water systems will be demanded as a city grows. If it does not look prosperous and so impress visitors it will not grow.

Before taking up a discussion of materials for paving, the writer wishes to offer an ordinance for the establishment of official elevations.

Do not establish elevations on the center lines. Each paving material requires a different crown and the elevation along the middle of the street fixes the elevations of the curbs. When materials are changed it means an increased or a lessened depth in the gutters, or else the curbs must be reset. The property owners set their floor lines with reference to the curbs. If every change in paving materials or every change in the width of the roadway alters the curb elevation, the property owner will never be secure in his mind.

Sometimes it is best to fix the official elevations at the property line and obtain the curb elevation from that. Sometimes it is best to establish the elevation on the curb. The writer prefers the first method. It gives the property owner a well established elevation to which to build. Future changes in the width of the sidewalk or of the roadway or a change in the paving material have then no terrors.

When that is done it is an easy matter to fix the elevations by ordinance so they can be always set. The ingenuity of the engineer will be called into play to describe the elevations and the points where they are fixed.

In order that elevations can be always referred to one plane of reference, an official base must be established. Then all points can be stated as being so many feet above or below the official base. It is usual to take the lowest point at which drainage is discharged and count it as having an elevation of zero or one hundred. If an elevation of zero is given, then there may be times when some work is done below that elevation, and this will necessitate minus elevations. The engineer can explain this to the non-technical

reader. It makes mistakes possible. It is better to assume that point as having an elevation of one hundred feet above city base, the base then being an imaginary plane. If on the sea coast, the mean of lower low tides is a good point to assume as being one hundred feet above city base.

ORDINANCE NO......

An Ordinance establishing a City Base, or Plane of reference for Elevations and fixing the elevation of a Primal Bench Mark.

The Common Council of ...... does ordain as follows:

Section 1.—That the Official City Base, or Plane of Reference for elevations in the City of .... is hereby fixed at a point one hundred (100) feet below the low water mark at .... street and .... street as ascertained on .... in the year ......

Section 2.—The cross cut in the top of the copper bolt set in the top of the concrete monument at the Northeast corner of the entrance to the City Hall on the ground floor is hereby declared to be the Primal Bench Mark of the City of .... and the elevation thereof is one hundred and ten feet and thirteen one-hundredths of a foot (110.13) above City Base.

Section 3.—All official elevations hereafter established in the City of .... shall be described with reference to their elevation as compared with the official base in feet and decimal parts of a foot. No grade or official elevation shall be established other than by ordinance and in the manner described in this ordinance.

Section 4.—This ordinance shall take effect and be in force on and after ....

ORDINANCE No......

An Ordinance establishing official elevations on .... street between .... street and .... street.

The Common Council of .... does ordain as follows:

Section 1.—The official elevations at the intersection of .... street and .... street are hereby fixed as follows, to-wit: At the Northeast corner .... feet (....) above City Base. At the Northwest corner .... feet

(....) above City Base. At the Southeast and Southwest corners .... feet (....) above City Base.

Section 2.—On .... street .... feet north of the north line of .... street .... feet (....) above city base.

Section 3.—At the intersection of .... street and .... street the official elevation at each corner shall be .... feet (....) above City Base.

Section 4.—The elevations mentioned in the preceding sections of this ordinance are fixed at the property lines.

Section 5.—The elevation of the curbs shall be fixed at the time the street is improved and the slope from the property line to the curb across the sidewalk shall not be less than one-eighth of an inch per foot (1/8") nor more than one-half of an inch (1/2") per foot.

Section 6.—The shape of the cross section and the elevations thereof shall be fixed at the time the street is improved, depending upon the material used for paving.

Section 7.—The longitudinal slope or grade of the street shall be on straight lines connecting the points where the elevations are fixed, as provided in this ordinance; excepting that where the grade breaks in the block between the intersecting streets the roadway and curbs shall be on vertical curves of such length and kind that the allowable cross slope of the sidewalks will be maintained.

Section 8.—The grades of the gutters shall be so fixed that the extreme height between the tops of the curbs and the bottoms of the gutters will not exceed one foot (1').

Section 9.—The official elevations of the corners of intersecting streets, alleys, places, lanes and other public places and highways, intersecting said street at points between points on which the official elevations are fixed by ordinance shall be, and are hereby, fixed at an elevation being on a straight line connecting the two established points nearest said intersecting corners.

Section 10.—All ordinances or parts of ordinances in conflict with this ordinance or any part of it, are hereby repealed as to the conflicting portions.

Section 11.—This ordinance shall take effect and be in force on and after ....

In establishing elevations at street crossings and intersections try and make them level. If the intersecting streets have grades of 3 per cent or more the crossing will have the appearance of pitching in toward the hill if made level. The best way to fix the intersection grade in that case is to make it equal to half the sum of the two grades but not to exceed three per cent.

A town is justified in going to considerable expense to secure level cross sections in business districts where the grades are less than five per cent.

In small cities and towns there exists an impression that all business streets have level cross sections. To attain this ideal a great deal more money is spent than is justified and this is one of the matters to be left wholly to the engineer to decide. As a fact a great many large cities have business streets with considerable difference between curb elevations.

STREET WORK.

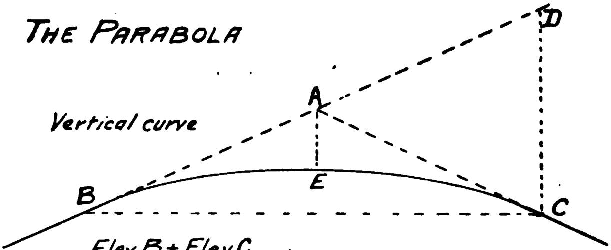
All grade ordinances should definitely fix the points where the elevations are established. The engineer is supposed to prepare all such matter carefully in his office before writing the ordinance. The writer thinks it best to have a vertical curve connect all changes of grade where they occur between intersecting streets. This will avoid the appearance of a break. He usually plots his grade line on a large scale and connects the inclinations with a parabola.

Fig. 1 is from Baker's Roads and Pavements. Professor Baker recommends that there should be from 10 to 15 feet of curve for each foot of change in elevation in one hundred feet.

Fig. 2 shows a method of calculating a parabola. It is used in forming a diagram for the cross section of a pavement between curbs.

Another method for describing the parabola is shown in Fig. 3. Divide the distance between the ends of the curve into any number of parts and place the numbers at the points as shown, commencing at each end. Multiply the two numbers at each point together.

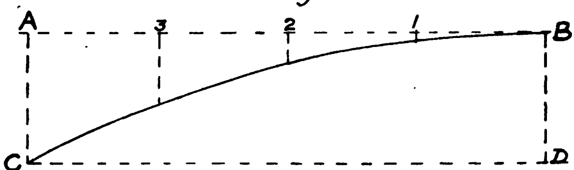
THE PARABOLA



$$\frac{Elev\,B + Elev\,C}{2} = y \qquad \frac{x - y}{2} = AE$$

$$Elev.\,A = x$$

Fig. 1



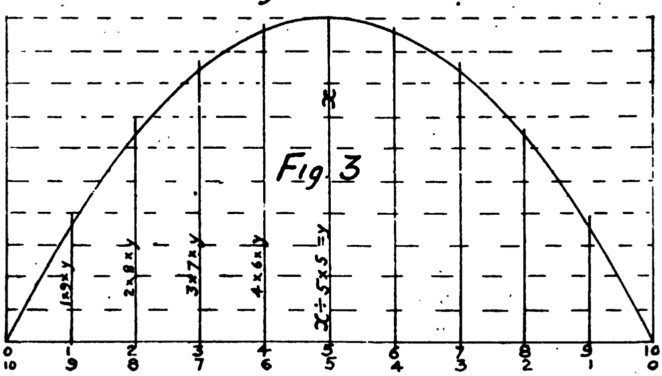
Divide half width of roadway into n parts.

$\frac{AC}{n^2} = x$ Distance down to surface from line

$AB = x$ at 1 $= 2^2 x$ at 2 or $4x$

$= 3^2 x$ at 3 or $9x$ etc.

Fig. 2.



Divide the total rise by the product of the two numbers at the middle point. Multiply the result successively by the products of the numbers at the other points. The results give the ordinates of the parabola. This method is also good for constructing a parabola for any purpose, such as finding the bending moments in beams uniformly loaded, the flow of a jet of water, etc.

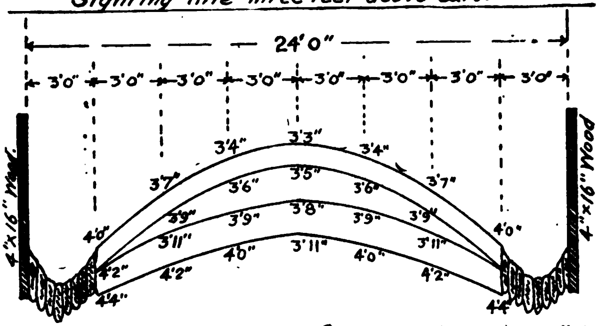
It is a good plan in preparing the grade ordinance to first plot the profile with the proposed grades; fix the vertical curve and take the elevations from the profile at intervals varying from fifteen to twenty-five feet and describe each in the ordinance. When the curb is put in there will be no breaks, for the slight angular point at each change can be adjusted on slight curves extending a few inches each way. Some care taken in the office work is well repaid.

Figs. 4 and 5 illustrate exaggerated diagrams given to contractors at a time the streets are improved. The curbs are supposed to be set first. With the use of boning rods the foreman can then fix the curve of the cross section exactly and the engineer does not have to be always on hand to give stakes. The rods are simple in construction and use.

Take a common lath three or four feet long and nail it to a piece of board about four inches wide and six inches long. Wrap a piece of white paper around the top of the lath. Set the base piece on top of the curb on one side of the street and place on it a brick or stone to hold it in place. Another lath of exactly the same length is held on the opposite curb to sight over. The third lath is divided into feet and inches and usually has a movable sight on it. Such a sight may be a piece of paper tied on so it can be moved up or down readily. The cheap yard sticks given away by stores are useful for the purpose instead of graduating a lath. This rod is held so the graduations read from the top down. The fixed rod is placed on one curb and the foreman takes his rod to the other and holds one end of a tape.

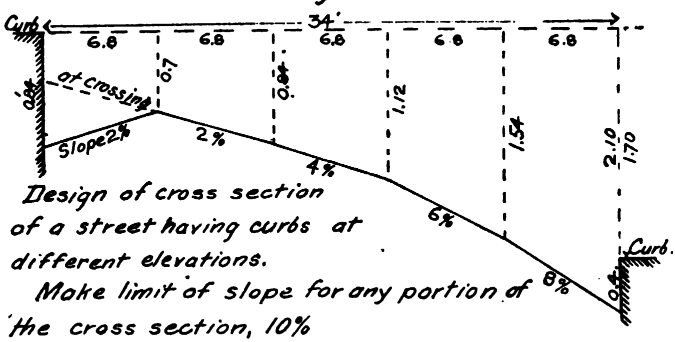
An assistant takes the graduated rod and the other end of the tape and measures each distance successively as called off. When a distance is measured the movable sight is set the proper distance down and the rod held on a stake. This stake is driven until the foreman sighting over the target can see the top of the opposite stake. In this way points can be set every ten feet, more or less, along the line of the street after the curbs are set. The diagram is

usually given on a piece of cross section or profile paper and the foreman can read the distance down at any desired distance from



Macadam in three layers. Gutters 3'0" wide. 3" deep.
Fig. 4

Fig. 5



Design of cross section of a street having curbs at different elevations.
Make limit of slope for any portion of the cross section, 10%

vide Holland Wheeler in Eng. News.

the curb. He does not therefore have to measure to the points marked if there is anything to prevent it. He can set stakes as close together as he wishes.

Common custom approves of the parabola as the best form for the cross section of a street. It is easy to put in for one thing. In some places instead of using the boning rods the engineer sets a stake the height of the crown. At half the distance to the curb set a stake with its top one-fourth the height below the crown. That is half way between the gutter and the crown the height is three-fourths the crown. Some engineers prefer two flat slopes from crown to gutter with a slight rounding at the intersection. Some prefer a segment of a circle. It is almost entirely a matter of taste, although the writer believes the parabola is best.

In an earlier chapter some rules were given for crown heights. Custom varies. In Boston, for macadam the rise is one-half inch per foot in width. For granite block, three-eighths of an inch. For asphalt or brick, five-sixteenths of an inch. In New York for asphalt, one-quarter of an inch and for brick or granite, three-eighths of an inch. In Chicago a minimum of two per cent and a maximum of five per cent of half width for asphalt, brick or granite. For macadam a minimum of four per cent and a maximum of eight per cent of the half width.

In Omaha the custom is to decrease the crown as the longitudinal slope increases. This is sensible and is now used in other places. The following formula for the crown of asphalt paved streets was originated by Andrew Rosewater, city engineer of Omaha:

$C = W\ (100-4p) \div 5{,}000$, where

C = crown of pavement in feet.

W = distance between curbs in feet.

p = % of longitudinal grade.

The crown for brick, wood or stone is five-sixths of the crown for asphalt, as such materials are not harmed by water standing on them. The above formula is for a level cross section.

Reference has been made to winding roadways on extremely steep streets. To study such a problem, make a contour map of the street on a scale of forty or fifty feet to an inch. For turning space at each side there should be about twenty feet. Draw on each side a line parallel with the side lines and twenty feet distant from them.

Draw a series of equilateral triangles between these twenty-foot lines. The sides of the triangles crossing the street indicate closely where the roadway may be located. The roadway should

be sixteen feet wide and the lines of the triangles cross it. That is, at the bottom the point of the triangle will be on the down hill side of the road. It will cross the roadway diagonally until at the other side of the street it will be on the up-hill side. Draw in the lines of the roadway in this way and when the twenty-foot strip is reached, carry the roadway lines across it at a right angle with the side of the street. This will then give plenty of space for a turn. Along the center line of the roadway as laid out thus, make a profile and then fix the grade, giving not to exceed three per cent on the turn. It is best to make it level. If there is a grade on the turn, make it on a curve with a radius of sixteen feet.

If the steep street is winding around a hill side instead of going straight up, the above procedure must be modified to suit conditions. The foregoing is only a suggestion, for every case demands special treatment.

Page after page of formulas can be given treating of intersection elevations. Few of them are worth bothering with. There will be slight necessity for any if the elevations are fixed at the side lines instead of on the center lines of streets. In a preceding chapter the treatment of intersections approached by streets with steep grades has been discussed.

The writer has often employed with benefit, models to illustrate his ideas to property owners and councilmen. A model of a hill-side street, showing the appearance before improvement (which every one will recognize), side by side with one showing the completed work, will sometimes advance proceedings several months and avoid many headaches and discussions.

The most simple way to make such a model is to transfer contours to pieces of board and saw the pieces with a scroll saw, to the shape indicated by the contour. The pieces are nailed together and present the appearance of steps. The steps can be filled with wax or cement or putty and given a smooth surface. A plaster-of-paris mold is taken of it and can be used as a mold for the construction of a light model of papier maché. Sometimes the original is colored and fixed up, but it is heavy. Sometimes cross sections are made of light wood and pieces of cardboard fastened to them and the whole frame covered with paper which is colored. Such a model is light, but fragile.

The minimum grade in gutters should be about six inches in one hundred feet or what is called a five-tenths grade.

On streets level, or nearly level, the following formula is used for putting in summits:

$$x = \left(\frac{L}{2}\right) - \left(\frac{D}{2R}\right)$$

where x = distance of summit from higher inlet.

L = distance between inlets.

R = grade of gutter (per cent).

D = difference in elevation of inlets.

A graphical method is often used in the office. Make two scales having the same number of divisions per inch as the scale of the map, but figured according to the per cent of grade instead of feet in distance. One scale begins at the right end with the elevation of the inlet at that end of the block. The other scale begins at the left end with the elevation of the inlet at that end. The scales are then numbered to correspond to the rise or fall. One scale is marked on the top edge of the strip and the other on the lower edge. Place the scales on the map with the graduated edges touching and with the ends placed at the inlets having corresponding elevations. It will be seen that at some point between the inlets the elevations on the scales correspond. This is the point where the summit should be placed, and the elevation of the summit is read off the two scales.

It is not necessary to make new scales for each block. Two can be made on bristol board and the figures placed on them lightly with lead pencil when required.

In a long block two summits are occasionally required when it is impossible to get a grade as good as five-tenths per cent with one summit. This will call then for an inlet near the middle of the block and the elevation and position can be calculated by the formula or fixed graphically. An experienced engineer can locate a summit with a glance at a contour map or profile.

CHAPTER III.

WALKS, CURBS AND GUTTERS.

The narrowest sidewalk should be at least five feet wide. If in a business district it should, of course, be wider and extend clear from the curb to the building line. In the residence districts it is better to have a grass plot on either side.

Wooden sidewalks are only temporary affairs and should not be allowed to remain after they commence to wear. The boards get loose and the nails work up. They trip the pedestrian in summer and squirt muddy water on him in wet weather. If used they should be made of planks two inches thick, not more than eight inches nor less than six inches wide, and be spiked with a 20-penny nail. The span between bearings should not be more than three feet so the walk will not be springy. The top of the spikes should be set at least one-quarter of an inch below the top of the plank. Narrow walks consisting of wide planks running lengthwise of the road should not be permitted.

A number of cities in the United States have judgments to the amount of hundreds of thousands of dollars hanging over them because of damage suits by reason of defective sidewalks made of wood. In consequence no wooden sidewalks can now be put down in those cities.

Cinder walks are very well liked, and in many districts too poor to afford permanent walks cinder sidewalks are put down. A plank is laid on edge on each side of the sidewalk space and the width between leveled off, after which cinders are put down in thin layers, each layer being wet and tamped.

Stone flag sidewalks are out of date. They wear unevenly and get loose after much travel.

Brick sidewalks of ordinary building brick soon go to pieces and become rough and dangerous. Brick sidewalks made of vitrified paving brick set in cement mortar are more satisfactory, but

a brick pavement is old fashioned and little, if any, cheaper than a cement sidewalk.

The best sidewalk is the concrete and cement walk properly laid. They should be put down under good specifications and competent supervision. Property owners putting down such walks by private contract should be compelled to comply with the city specifications.

The glare of the light colored cement sidewalk on a sunshiny day is objectionable but may be overcome. By the use of lampblack or other pigments the color of the sidewalk can be greatly modified.

A good strong ordinance should be passed providing for putting down concrete and cement walks. No one should be permitted to engage in the business until he can show he is experienced in the work. He should pay a good license and put up a bond to protect the city in case his sidewalks go to pieces inside of two years. If a sidewalk built by him begins to break up within two years his license should be taken away from him and his bondsmen should be made to rebuild the walk. Every sidewalk contractor in this material should have a name plate and stamp his name at distances not exceeding twenty-five feet on each piece of sidewalk he puts down, together with the year and month. His sidewalks will thus advertise his work. A good cement walk should last several generations.

It is becoming common nowadays to have the names of streets set into sidewalks at corners, or into the curbs if concrete curbs are used. The contractor easily arranges this by having letters made of metal, which are oiled and laid on the base before the finishing coat is placed. When the finishing is done the letters are taken out, which is an easy thing because of the oil, and the space filled with colored cement mortar. The names should be placed at the ends of the cross walks.

CURBING.

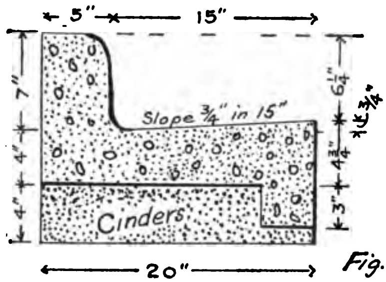
7 Curbing is placed as a division line between the sidewalk and roadway.

Charles Mulford Robinson, whom the Good Roads Magazine styles the "American authority on the city beautiful," has the following to say about curbing in a recent report to the city council

of Colorado Springs, Colo.: "It is necessary æsthetically as well as practically, with brick and block pavements; it is by no means appropriate artistically where pavements are of gravel or macadam; is not often essential where such a roadway is narrow; and here may be a positively bad thing practically, since it prevents surface water from reaching the turf and roots of trees that it might otherwise do much to help."

In this connection Mr. Mulford was speaking of the parking of streets, mentioned in Chapter II. For such streets the writer agrees with Mr. Mulford.

On macadam or gravel streets not parked, wooden curbs are often used. The best are sixteen inches deep and four inches thick. The grade, or official elevation, on the top of the curb should be two inches below the elevations established by ordinance. This will allow wooden sidewalks to be laid to grade and be spiked to the top of the curb, resting on it.



CONCRETE CURB and GUTTER.

The toe is only used when pavement has no concrete base and is on steep grade.

Fig. 1.

Granite curbs are generally set in pieces from four to eight feet long. They go into the ground from six to twenty-four inches, projecting from six to twelve inches. They are generally six inches thick at the top and eight inches thick at the bottom. The top is dressed and so is the exposed face. If the climate is severe the curbs are sometimes placed on a cinder or brick foundation going below frost line. The tops of the curbs are set at the official elevations established by ordinance and sidewalks are laid flush with the tops.

Stone curbs are going out of use nearly everywhere. The short pieces are hard to keep in line and the appearance soon

becomes bad. It is difficult to secure good stone and the monolithic concrete curb is more durable and presents a handsomer appearance, besides which it is usually lower in first cost.

The shaping of corners presents considerable variety. The most handsome corner is one where the two intersecting curbs meet in a circle having a radius equal to the width of the narrower walk. This is an additional reason for using concrete curbing, as the forms can be made for any radius. When granite curbs are used the corners are generally of very short radius, for curved stones cost much more than straight pieces, whereas for concrete there is no additional cost after the forms are made.

To save the expense of making too many forms some towns have a common radius of ten feet. But many cities use curves with a radius as small as three feet and some of only eighteen inches. The appearance of such corners is not good. They jut out into the roadway too far and for vehicles are not so good as the larger curve.

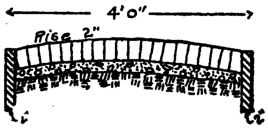
There are three ways of making wooden corners. In one the pieces are cut into lengths of one foot with an inside bevel on each end. Placed on a curve with the ends of the pieces spiked together the corner looks well but is weak until the sidewalk planks are spiked to it. Sometimes several 4-in. x 4-in. posts are driven in the ground on a circle four inches back from the face of the curb. The posts are about three feet apart. Four thicknesses of one-inch boards are bent around these posts and spiked thoroughly to them as well as to each other. Or two planks are sawed on a curve and short vertical pieces four inches wide and slightly bevelled on the edges are attached vertically to them. When finished it looks like the inside form for a concrete curb. This is set in place and when the earth is filled back of it the appearance is good. The writer has visited cities where rounded wooden corners were made by driving, on a circle, 2-in. x 4-in. pieces into the ground touching each other and then bending a one-inch board around the outside.

The top of the curb should not be more than one foot above the bottom of the gutter. If possible it should not exceed ten inches. It is often necessary to have a shallow gutter at the middle of the block and a deep one at the catch basin in order to

make a good grade in the gutter. The gutter is said to have a summit where the curb is low.

CROSS WALKS.

It is usual to provide cross walks on streets not improved or on streets improved with gravel or macadam.



Crosswalk of Brick or Stone showing Plank edge. Same form may be used for Concrete.
Fig. 2

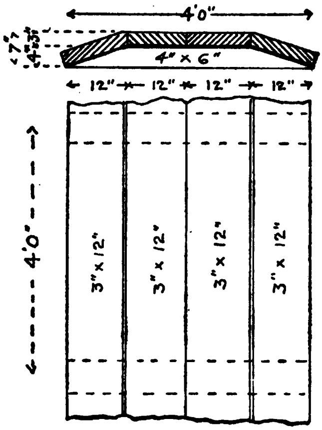
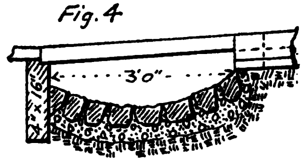


Fig. 4

A form of gutter at crossing, commonly used with asphalt.
Fig. 3



Wood Crosswalk, on macadam or earth road with wood curb and stone gutter.

For earth and gravel streets the cross walk is usually of wood. The form is generally the same in all places. Cross pieces six inches wide and four inches deep are spaced four feet apart across the roadway. For a distance of one foot on each end they are bevelled down to an edge. On this bevel is spiked a three-inch

plank and across the level top is spiked other three-inch planks to make the width preferred in that particular place. Usually such a cross walk is six or eight feet wide on top at intersections with, and across, the main street, and on side streets is from three to four feet wide. The width in the bevel is of course no use for walking on and is only there to assist wagons up the slope. The crossing usually is shaped to the cross section of the roadway, except close to the gutters, and the stringers are set flush. The top planks, therefore, rest on the road and the sloping planks are partly bedded in it.

On a gravel or dirt road it is usual to place large broken stones under the planks and between the stringers to provide ventilation for the planks, at the same time acting as a support.

At a distance of three or four feet from the curb the top planks change direction so they will rest on it and the bevelled planks are stopped. This gives a continuous walk across the street and leaves space for the gutter underneath.

For macadam streets the cross walks may be of wood, stone, brick or concrete. The widths are settled according to the fancy of the parties putting them in. No walk should be less than three feet wide and wider walks should be used on main streets.

Wooden cross walks are like those above described. Brick cross walks are made of vitrified paving brick set on edge and grouted between the joints with cement. It is a good plan to set a two-inch plank on edge on each side of a brick walk to take the shocks of wheels. The top of the plank to be level with the top of the brick at the edge. The walk should be slightly crowned (about two inches in a five-foot walk and proportionately less for narrow walks) to prevent water standing on it and to make it sightly in appearance.

Concrete cross walks should be slightly crowned, as for brick cross walks, and they also should have a wooden plank on edge to take shocks. The writer prefers, however, in the case of concrete cross walks to place an edging of stone blocks between the concrete and the plank. Concrete cross walks are very handsome and look well if care is taken to prevent a break on the edge. Somehow concrete goes to pieces rapidly after it starts.

Stone cross walks may be constructed of ordinary stone paving blocks, of large flat flags, or of rubble. Stone paving blocks

are the best and should be laid close together and be grouted in the joints with cement grout. Large stone flags are difficult to get, are seldom smooth and generally too expensive considering the lack of appearance.

A rubble stone cross walk is made by smoothing off the space and tamping it hard. Set a thick plank on edge on each side and cover the space with a stiff cement mortar mixed one to three, about one inch thick. Bed in this stones from four to eight inches square on top and as nearly cubical in shape as can be procured without taking special pains to cut them. The top should be smooth as possible and the stones are to be pressed into the mortar below so they will form an even surface on top for the walk. After the stones are all set pour between the joints a thin soft mixture of one to three cement mortar until the spaces and joints are filled flush. When the mortar sets the top of the walk looks like mosaic work. Such a walk looks well if slightly crowned. It is very good looking and durable, while not so expensive as either brick, cut stone, or concrete.

The cross walk follows the cross section of the street until it gets within five or six feet of the curb. Then it goes on a straight line for the top of the curb. Within about three feet it stops and ends at a concrete curb as a sort of small retaining wall. This wall goes gradually down on a slope on each side until at a distance of about two feet each side of the walk it reaches the street surface. It has a recess cut in the top opposite a similar recess on the sidewalk curb. This is to receive the ends of planks serving to bridge the gutter, or iron plates that are sometimes used for the same purpose. Some cities have the cross walk come within one foot of the curb and have no bridge plank or cover.

Streets that are paved with any of the more durable and modern pavements have no cross walks. At the place where the crossing comes the curb parallel with the sidewalk curb is put in place and the cross section of the street at the crossing point is altered so it makes practically a level crossing from curb to curb. It is seldom that with such crossings any covering is put over the gutter opening. The writer, however, always prefers the gutter coverings and to have the area larger than is customary where they are not used.

GUTTERS.

Gutters on earth roads are generally ditches of considerable depth in the outlying districts and are merely rounded edges of the roads with a depression of from six inches to one foot, in the more settled parts of town.

For macadam or gravel roadways on parked streets the gutters should be nicely rounded depressions not more than four inches deep and from two to three feet wide nicely paved with cobbles or flat stones or paving brick. They make a good looking division between the roadway and the grass.

On macadam or gravel streets not parked, the gutters where wooden curbs are used generally consist of a wide plank spiked to the curb at a slight angle. This plank is practically on a continuation of the slope of the roadway toward the curb. It is better, however, to make a gutter three feet wide of stones grouted in the joints with cement mortar.

The specification is as follows, for this as well as for the gutter in the parked roadway:

> "The gutter shall consist of stones not less than four inches nor more than eight inches in any dimension, laid with the flat side uppermost in a bed of cement mortar composed of one (1) part of approved Portland cement and three (3) parts of clean coarse sand. Spalls shall be used to partially fill the interstices and the upper surface shall be well formed and laid to the lines set by the engineer. The bottom shall be a circular arc. After the stones are laid in place and the surface pronounced satisfactory by the engineer the contractor shall fill all the interstices with a cement grout composed of one (1) part of approved Portland cement and three (3) parts of clean coarse sand mixed with enough water to make it about the consistency of heavy oil. The grout shall be poured into the interstices from a spout and shall not be laid over the surface and swept in with brooms. The interstices must be well filled with the grout to make the gutter solid and strong, and to prevent the stones from being washed out by a rush of water."

For a gutter composed of brick or stone blocks the specifications should provide for a bed two inches thick of cement mor-

tar in which the brick or the stone should be imbedded and the pieces laid together as closely as possible. They should be laid with the length in the direction of the street. Grout should be poured into the interstices as specified for the stone gutter.

When brick, wood, stone block or asphalt pavements are laid it is usual to have the pavement continue to the curb with no special provision for a gutter. It is becoming the custom now to have a combined concrete curb and gutter for all streets except those paved with macadam or gravel.

When macadam streets are tarred, or treated in a way that tends to preserve them, the concrete gutter may be used. Otherwise it is out of place on a macadam street.

In towns where horses are standing at the curbs for hours at a time it is good policy to make gutters of vitrified brick, or stone blocks, about six or eight feet wide on all streets improved with gravel or macadam or paved with asphalt, tar or similar materials.

The continual moisture and the almost continual pawing of iron shod hoofs make macadam and gravel and asphalt streets go to pieces in a short time.

Within the past year the writer has noticed several very wide gutters made of concrete blocked off like paving brick or stone.

These gutters presented a neat appearance and have proven durable when well made. Because of the fact that good concrete material can be obtained nearly everywhere, many cities will use such gutters where heretofore the difficulty and expense of securing suitable paving stone or brick have held back needed improvements.

USUAL SPECIFICATIONS FOR CONCRETE SIDEWALKS.

All cutting and filling necessary to bring the foundation to subgrade as given by the engineer in charge of the work, must be done by the contractor. When necessary the foundation must be consolidated by wetting and by rolling or ramming to give it proper stability. Soft and spongy places not affording a firm foundation must be dug out and refilled with sand or gravel, and well compacted by ramming, and foundation brought to within four and one-half (4½") inches of the grade.

(NOTE—The writer believes that under the sidewalk should be placed two or three inches of cinders well compacted, or about one inch of sand if the subsurface is a clay, and there should be drains laid from the cinders or sand to the nearest manhole or catchbasin. This is not necessary if the soil be a porous one.)

On the surface thus prepared shall be placed a layer of hydraulic cement

concrete for four (4) inches in thickness, composed of one part of approved Portland cement, two parts best clean, coarse, sharp sand. After mixing, dry, five parts of broken stone, of a size not larger than two and one-half (2½) inches in any dimension, shall be added, and then water added in just sufficient quantity as will give a surplus of moisture when rammed (or a concrete mixer may be used).

The second layer or finishing coat, one-half (½) inch in thickness, to be made of one part of approved Portland cement and one part torpedo gravel to be used before the first layer has set. In both foundation and surface coats joints shall be made with tar paper or by means of removable plates or boards to form expansion joints or planes of weakness. The squares shall be not to exceed ten feet in size. The surface shall not be dusted with dry cement and shall be thoroughly trowelled and floated smooth.

When completed, the surface shall be covered with sand, straw, hay or cloth and kept wet for not less than six days, and the material covering it shall then be allowed two days in which to dry before being removed and exposing the surface to the direct rays of the sun.

The contractor shall clean up when the work is completed and remove everything not necessary to be left so the immediate vicinity of the work shall be in as good and presentable condition as before he commenced his work.

The undersigned hereby certifies that he has read the foregoing specifications, and that the proposal for the work is based on the conditions and requirements embodied therein, and should the contract be awarded to him, he agrees to execute the work in strict accordance therewith.

Specifications for combined curb and gutter are given in the Chicago and Richmond, Ind., specifications.

Specifications for concrete crosswalks can safely follow the concrete roadway specifications used in Richmond, Ind.

NATIONAL ASSOCIATION OF CEMENT USERS. PHILADELPHIA, PA.

STANDARD SPECIFICATIONS FOR PORTLAND CEMENT SIDEWALKS.

Adopted January 24, 1908.

MATERIALS.

The cement shall meet the requirements of the specifications for Portland cement of the American Society for Testing Materials, and adopted by the National Association of Cement Users, January, 1905.

Sand shall pass a No. 4 screen and be free from foreign matter, excepting loam or clay, which will be permitted if the quantity does not exceed five (5) per cent. and when these ingredients do not occur as a coating on the sand grains.

Not more than 40 per cent. shall be retained on a No. 10 sieve.

Or 35% pass a No.	10 and be retained on a No.	20	sieve.
"	20 "	30	"
"	30 "	40	"
"	40 "	50	"

Not more than 20% shall pass a No. 50 sieve.

Or 70% pass a No.	10 and be retained on a No	40	sieve.
"	20 "	50	"

Stone shall be crushed from clean, sound, hard, durable rock, be screened dry through a ¾-in. mesh, and be retained on a ¼-in. mesh.

Screenings from the crushed stone specified above, which shall meet the requirements for sand, may be substituted for sand if so approved.

Gravel shall be clean, hard and vary in sizes from that retained on a one-quarter (¼) in. mesh to that passed by a three-quarter (¾) in. mesh.

Unscreened gravel shall be clean, hard and contain no particles larger than three-quarters (¾) in. The proportions of fine and coarse particles must be determined and corrected to agree with the requirements for concrete.

Water shall be reasonably clean, free from oil, sulphuric acid and strong alkalies.

FORMS.

Forms shall be of lumber, free from warp, and not less than one and three-quarters (1¾) in. thick. All mortar and dirt shall be removed from forms that have been previously used.

The forms shall be well staked to the established lines and grades, and their upper edges shall conform with finished grade of the sidewalk, which shall have sufficient rise from the curb to provide proper drainage; but this rise shall not exceed one-quarter (¼) of an inch per foot, except where such rise shall parallel the length of the walk.

At each block division, cross forms shall be put in the full width of the walk and at right angles to the side forms.

A metal parting strip one-half (½) in. thick shall take the place of the cross-forms at least once in every fifty (50) linear feet of sidewalk. When the sidewalk has become sufficiently hard, this parting-strip shall be removed and the joint filled with suitable material prior to opening the walk to traffic. Similar joints shall be provided where new sidewalks abut curbing or other artificial stone sidewalk.

All forms shall be thoroughly wetted before any material is deposited against them.

SIZE AND THICKNESS OF BLOCKS.

In business districts blocks shall be so divided that no dimensions shall be greater than six (6) ft.; thickness of sidewalk shall correspond directly with the greatest dimensions of the walk, as follows:

Block	6 x 6 ft.;	thickness	6 in.
"	5 x 5 "	"	5½ "
"	4½ x 4½ "	"	5 "
"	4 x 4 "	"	4 "

In residence districts the thickness shall be as follows:

Block	6 x 6 ft.;	thickness,	6 in.
"	5 x 5 "	"	5 "
"	4 x 4 "	"	4 "
"	3 x 3 "	"	3 "

In residence sidewalks it shall be permissible to lay sidewalks with a thickness at the edges twenty-five (25) per cent less than the thickness at the center

In no case shall the thickness of the walk be less than three (3) inches.

SUB-BASE.

The sub-base shall be thoroughly rammed, and all soft spots removed and replaced by some suitable hard material.

When a fill exceeding one foot in thickness is required, it shall be thoroughly compacted by flooding and tamping in layers of not exceeding six (6) inches, and shall have a slope of not less than one to one and a half.

The top of all fills shall extend at least 12 in. beyond the sidewalk.

While compacting, the sub-base shall be thoroughly wetted and shall be maintained in that condition until the concrete is deposited.

BASE.

The concrete for the base shall be so proportioned that the cement shall overfill the voids in the sand by at least five (5) per cent. and the mortar shall overfill the voids in the stone or gravel by at least ten (10) per cent. The proportions shall not exceed one (1) part of cement to eight (8) parts of the other materials.

When the voids are not determined, the concrete shall have the proportions of one (1) part cement, three (3) parts sand or screenings and five (5) parts stone or gravel. A sack of cement (94 pounds) shall be considered to have a volume of one (1) cubic foot.

To determine voids, fill a vessel with sand and let net weight of sand equal *B*. Fill same vessel with water and let net weight of water equal *A*.

$$\text{Per cent. voids} = \frac{A \times 2.65 - B}{A \times 2.65}\ 100$$

This formula may also be used in determining voids in crushed stone and screenings by substituting for 2.65 the specific gravity of the stone.

The following is a more simple method for determining voids in coarse aggregate: Fill a vessel with the aggregate and let net weight equal *B*. Add water slowly until it just appears on the surface and weigh. Let net weight equal *A*. Fill same vessel with water and let net weight equal *C*.

$$\text{Per cent. voids} = \frac{A - B}{C}\ 100$$

Use a vessel of not less than one-half (½) cu. ft. capacity. The larger the vessel the more accurate the result.

(*a*) *Hand Mixing:*

The sand shall be evenly spread on a level water-tight platform, and the cement spread upon the sand. After thoroughly mixing dry, to a uniform color, water shall be added in a spray, and the mass turned until homogeneous mortar of even consistency is obtained. To this mortar shall be added the required amount of stone or gravel previously drenched, and the whole shall then be mixed until all the aggregate is thoroughly coated with mortar.

Where unscreened gravel is used, the cement and gravel shall be thoroughly mixed dry, until no streaks of cement are visible. Water shall be added with a spray in sufficient quantity to render, when thoroughly mixed, a concrete equivalent to that specified above.

Water may be added during the process of mixing, but the concrete shall be turned at least once immediately after its addition.

(*b*) *Mechanical Mixing:*

Machine mixing will be acceptable when a concrete equivalent in quality to that specified above is obtained. The mixing of mortar and concrete shall be thorough and satisfactory to the engineer.

Retempering will not be permitted.

The concrete shall be deposited within sixty (60) minutes after being mixed, and shall be transferred to the forms in water-tight wheelbarrows. The wheelbarrows shall not be filled so full as to permit mortar to slop out, and shall not be run over the freshly laid concrete.

The concrete shall be spread evenly and tamped until water flushes to the top.

Separation of the blocks should be done with a tool not over six (6) in. wide and one-quarter (¼) in. thick, and to insure complete separation the groove should be cut through into the sub-base. Fill the groove with dry sand before the top coat is spread, and the top coat should be cut through to the sand after floating and troweling and a jointer run in the groove; then again draw a trowel through the groove, so as to insure a complete separation of the block.

Workmen shall not be permitted to walk on freshly laid concrete, and where sand or dust collects on the base it shall be carefully removed before the wearing surface is applied.

WEARING SURFACE.

The wearing course shall have a thickness of at least three-quarters (¾) of an inch.

The mortar shall be mixed in the same manner as the mortar for the base, but the proportion of one (1) cement to two (2) of sand or screenings, and it shall be of such consistency as will not require tamping, but will be readily floated with a straight-edge.

The mortar shall be spread on the base within thirty (30) minutes after mixing, and in no case shall more than fifty (50) minutes elapse between the time that the concrete for the base is mixed and the time that the wearing course is floated. A thin coat of mortar shall be floated on the base before spreading the wearing surface.

After being worked to an approximately true surface, the block markings shall be made directly over the joints in the base with a tool which shall be cut clear through to the base and completely separate the wearing courses of adjacent blocks.

The blocks shall be rounded on all surface edges to a radius of not less than one-quarter (¼) inch.

When partially set, the surface shall be troweled smooth.

On grades exceeding five (5) per cent, the surface shall be roughened. This may be done by the use of a grooving tool, toothed roller, brush, wooden float or other suitable tool; or by working coarse sand or screenings into the surface.

If color is desired, only mineral colors shall be used, which shall be incorporated with the entire wearing surface.

SINGLE COAT WORK.

Single coat work shall be composed of one part cement, two parts of sand and four parts of gravel or crushed stone, and the blocks separated as provided for in the specifications for two-coat work.

The concrete shall be firmly compacted by tamping and evenly struck off and smoothed to the top of the mold. Then, with a suitably grooved tool, the coarser particles of the concrete tamped to the necessary depth so as to finish the same as two-coat work.

PROTECTION AND GRADING.

When completed, the sidewalk shall be kept moist and protected from traffic and the elements for at least three days. The forms shall be removed with great care, and upon their removal earth shall be banked against the edges of the walk.

Grading after the walks are ready for use should be on the curb side of the sidewalk, one and one-half (1½) ins. lower than the sidewalk, and not less than one-quarter (¼) in. to the foot fall towards the curb or gutter. On the property side of the walk the ground should be graded back at least two (2) ft. and not lower than the walk; this will insure the frost throwing the walk alike on both sides.

CHAPTER IV.

STREET PAVEMENTS.

It is an axiom in street paving, as in most other work that the material lowest in first cost is generally highest in cost of maintenance. Therefore get the best pavement the tax payers can afford. But it is sometimes better to put down some material to be replaced later by a better than to postpone an improvement indefinitely. Sometimes a cheap pavement arouses enthusiasm and causes an improvement boom where a more expensive pavement might be so ruinous to purses that it would actually retard all desire for improvement.

It is easy to generalize and easy to give the experience of other cities. The average tax payer will not be inclined to take another person's word, but will judge for himself when it comes to spending money for improvements.

Away from cities with good railroad communication the question of material for street paving is entirely local. Where one material can be laid down as cheaply as another the fancy of the individual may be indulged and the city streets be a patchwork if the people vote that way. When freight rates are high and first-class material is imported at great cost the question is a burning one. This should be remembered in reading articles on paving in magazines and other publications. The writer in New York or London can not settle the question for the people of Timbuctoo nearly so well as the people of Timbuctoo can for themselves, after they have had a little education and have obtained some ideas on the comparative values of the different materials most used.

Local considerations largely govern. One is the freight rate on the materials usually considered best and the proximity of ma-

terials, suitable for pavements, usually given a lower place. Another is the necessity for skilled supervision of certain pavements during construction. If the local engineer has not enough of the requisite scientific knowledge to know that a first-class job is being secured and the city can not afford to employ the man with the knowledge and experience, some materials must be barred out. Another is experience in maintaining certain pavements. If the city has not the proper men and can not afford them then another material will be barred out.

Each place must study carefully all the local conditions and improve the streets in the best way possible in that particular locality with reference to the good of the community and the least legitimate cost. Any of the leading materials will make a first-class pavement under proper conditions. It only requires common sense and a proper regard for the value of the opinions of men trained in the work; and possessed likewise of common sense, so their experience is of value to those who employ them.

No street will last forever without some sort of maintenance and system for repairing. Constant attention is required and there must be wise ordinances well enforced to keep the streets properly preserved, in a state to travel upon with comfort and satisfaction.

In the case of macadamized streets it has been found by actual observation that the cost of maintenance is one-third greater after the putting down of street car tracks. On such a street a T rail can be used under proper specifications, but a provision should be placed in the franchise providing that some other form (preferably a grooved girder rail) shall be put in when the street is paved with wood, stone, brick, asphalt or other material better than macadam.

It has been proven that street car tracks on a street shorten the life of any pavement placed thereon. When franchises are granted for street railways the manner of constructing the road bed should be carefully specified and the form of rail to be used should also be specified. The street railway company should also pay a part of the maintenance cost.

If an electric road operated by a trolley is to use the streets the double trolley system should be used, as there will be less danger from electrolysis. In the single trolley system the return current goes back underground and at every possible opportunity it attacks metal pipes in the ground. When an electric road is to be built

the city should employ a competent electrical engineer to prepare the specifications for doing the work and have him send an inspector to see that the work is done right. No road should be built without the city taking some such means for protection.

To avoid destroying a street by too frequent openings for water, light and sewer connections, some regulation of pipe laying is necessary. It is well enough to have specifications for the opening of the streets and the restoration of the surface, but the inspection is too often slighted.

The best way is to require all pipes (other than sewers) to be laid at definite depths and at definite distances from the property lines. On streets going in one direction the depths and distances will be different from those required on intersecting streets. At least twelve months before the street is paved all water, gas and sewer connections should be made. The best plan is to require service pipes and drains to be laid every 25 feet on each side of the street to a point one foot inside the curb line. When connections are afterwards made to the houses no openings will be necessary in the roadway.

Maps of all the pipe lines showing the location and depths of house connections should be kept in the office of the city engineer. See Chapter XII.

The question of street paving materials is a burning one. It is not settled. When a town becomes a city of about 20,000 inhabitants the Council awakes to the fact that some decision should be arrived at regarding the best material to use and committees are sent to cities near by to investigate conditions. They are usually met by the agent for some particular material and shown the work his company is doing.

In the meantime the city engineer formulates questions and sends them with stamped, addressed envelopes to all the cities he knows of, having about the population of his city. If half the papers come back he is pleased, for so much of this is done that few men care to bother with replies. The writer knew of one city sending out five hundred letters of inquiry and receiving twenty-seven replies.

From the data thus obtained the engineer makes out tables and prepares a report. Frequently he rushes into print with it. The writer has reports in his possession made from data thus obtained

and some men recommend one material and some men recommend another, as most suitable for their particular case.

Apart from strictly local considerations the following points are to be taken into consideration in selecting a material for street paving: Appearance, ease of traction, cleanliness, healthfulness, noise and cost. The ideal pavement is durable, noiseless, cleanly, healthful, easy to travel on and cheap. The ideal pavement has not come into use so far as the writer knows. The best we can do is to approximate to it, although there are men selling certain materials who have tables of percentages to prove their pavement is the ideal.

The loads a horse can draw on a perfectly level roadway each day is given by Haswell as follows:

Asphalt	6,095	pounds
Stone block	3,006	"
Ordinary stone block	1,828	"
Hard macadam	1,391	"
Hard gravel	1,279	"
Hard earth	1,193	"
Worn stone block	1,137	"
Cobble stone	730	"
Ordinary earth	456	"
Sand	228	"

Brick had not come in as a paving material when that table was prepared, but it is close to asphalt. Wood should have been mentioned, but a properly constructed wood pavement is as good as asphalt.

The following figures given by asphalt companies show the comparative cost of haulage on streets paved with various materials. There is little reason to doubt their close agreement with observation, even if presented by parties advertising a particular material.

Cost to move one ton one mile by horse power (estimate made in Indiana):

Asphalt	2.7 cts.
Block stone pavement (average)	5.3 cts.
Macadam in good order	8.0 cts.
Gravel road	8.8 cts.
Earth road, hard and dry	18.0 cts.
Macadam with ruts	26.0 cts.

Wet sand ....32.0 cts.
Earth road with ruts and mud..........39.0 cts.
Dry sand ....64.0 cts.

It will be noticed that there is no mention made of brick or wood in the above table. The cost is practically the same as for asphalt.

TABLE I.

VALUES OF PAVEMENTS.

Re-arranged from Baker's Roads and Pavements.

QUALITIES.	PERCENTAGE assigned to quality.						
	Ideal Pavement.	Sheet Asphalt.	Brick on Concrete.	Rectangular Wood Block.	Macadam.	Gravel.	Granite Block on Concrete.
ECONOMIC.							
Low first cost	15	6	9	8	10	15	3
Low cost of maintenance	20	16	14	12	8	6	20
Ease of traction	10	10	8	7	6	5	3
Good foothold	5	2	4	1	5	5	3
Ease of cleaning	10	10	9	9	3	1	6
Total	60	44	44	37	32	32	35
SANITARY.							
Noiselessnese	15	10	7	13	15	15	2
Healthfulness	10	10	8	5	6	6	7
Total	25	20	15	18	21	21	9
ACCEPTABILITY.							
Free from mud and dust	10	10	9	7	3	1	8
Comfortable to use	3	2	1	2	3	3	0
Non absorbent of heat	2	1	1	1	2	2	1
Total	15	13	11	10	8	6	9
GRAND TOTAL	100	77	70	65	61	59	53

Table I has been taken from Baker's Roads and Pavements, with a slight rearrangement of the columns. No changes have been

made in the figures, however. The table has been made from reports received from many cities, most of them of considerable size. Other men give values considerably different and the writer has found that the values assigned vary with the average sizes of the places from which reports are received and the completeness of the reports. The town also from which a favorable report was received on one pavement may have been close to a city where there were many first-class contractors laying it. The town condemning it may be far away from good contractors. The table, however is interesting.

Mr. T. J. McCarthy, assistant city engineer of Holyoke, Mass., received a great many inquiries about the experience of that city with various materials and prepared Table II to send to inquirers.

It will be noticed that he tells the kinds of foundations used for different materials. This is an important point. The subsurface should be thoroughly compacted and the writer believes it should in all cases be underdrained with the tile leading to the nearest manhole or catch basin. All modern pavements should have a concrete foundation. As natural cement may be hurt by frost, the cement used should be Portland where the weather conditions are severe. The writer is opposed to pavement foundations of brick, or old gravel or macadam.

EARTH ROADS.

A town first tinkers with the old earth roads when people get tired of mud. It buys a road machine, which has to be rebuilt every spring because no care is taken of it between while, and buys a road roller. The streets are rounded this year according to the ideas of one man who knows little about it and next year of a man who knows less. A well made, well kept and thoroughly rolled earth road is very satisfactory in dry weather. It is pleasant to use when not dusty or muddy. Seeing that it is either the one or the other all the time, earth roads are counted as not just the thing for progressive places.

GRAVEL ROADS.

Gravel is the first improvement tried. The ideas of men differ exceedingly as to what constitutes a good gravel for road work. In fact, their ideas differ as to what may be termed gravel One

kind is very fine and has sharp edges and angles. It is never found rounded like marbles or cobblestones and is pretty fair material to use on streets with little travel. Although the writer gives a form

TABLE II.

Comparative values of Pavements used in HOLYOKE, MASS. as determined by J. T. McCarthy, C.E. Asst City Engineer.

Kind of Pavement.	When laid.	Estimated life, in years.	Cost per sq. yd.	Average cost of maintenance per square yard per year.	Total cost per square yard per year.	Grade in use.	Safe maximum grade.	Cleanliness.	Slipperiness.	Noiselessness.
Granite Block	1882	50	$2.75	$0.03	$0.085	10%	10%	40	90	10
Asphalt block	1891	15	2.83	0.02	0.21	1.5	4	75	40	60
Wood block	1904	-	2.83	-	-	0.5	3.5	70	30	100
Vitrified brick	1897	25	2.02	-	0.08	6	9	80	80	35
Common brick	1898	10	1.75	-	0.175	4	8	75	85	35
Sheet asphalt	1905	-	1.86	-	-	4	4	100	35	65
Bit. macadam	1902	-	2.25	-	-	5	4	85	40	55
Macadam	1894	8	0.60	0.02	0.095	8	10	20	100	75

Wood block, 4½" conc. base 1-3-7; ½" mortar, 3" block, sand filler.
Vit. brick, 4" conc. base 1-3-7; 2" sand, 4" brick, Port. cem. grout.
Sheet asphalt, 5" conc. base 1-3-7; 1" binder, 1½" wearing surface.
Bit. macadam, 4" broken stone, 1½" binder, ½" " "

from Engineering News, March 1, 1906.

of specification for it, he wishes to say it is a most expensive material. If rounded river gravel is used there is no improvement at all. Gravel really has a place only in parks, for it is agreeable

to travel on and somehow fits park surroundings. Asphalt is out of place in a park.

When stone is used for a pavement it packs and binds partly by reason of the corners and angles interlocking and preventing any movement. But if the stone have round sides and there are no angles or corners it must be held together by means of some binder or cementing material. If this material sets and never softens, as in the case of hydraulic cement, then there can be no objection. But if the binder is clay or earth which will soften when wet, the stone gets a chance to move around and the larger pieces work to the top by reason of the smaller ones working down as they move under the traffic and the cementing material thus acts as a lubricant. Yet many people advocate gravel because it costs little at first and because it will "let the water through." This after a century of education in roadmaking.

It is highly desirable that the earth on which the road metalling rests should be porous and easily drained, but the endeavor of the engineer is to get an impervious covering, which is termed "metalling" when composed of gravel, cinders, broken stone, etc., and which is termed "paving" when composed of something more durable in use and neater in appearance.

The only way to use round gravel is to put it through a rock crusher and when it goes through call it macadam and put it on the road in accordance with the best possible specifications for macadamizing.

MACADAM ROADS.

Macadam is far superior to earth and gravel. It retains a hold on people, for it is low in first cost and a pleasant material in the right kind of weather (one or two months in the year). It is a good material with which to start the street improvement ball rolling, but no town or city should accept a macadam street to keep it in repair. A street should not be accepted until it is paved, and macadam is not a pavement. It can be used on any grade that a load can be hauled on and is a quiet material, so remains a favorite for residence streets. These streets should be improved at low cost and as the travel on them is not heavy the cost of maintenance is not a large factor, considering how free from noise and how satisfactory in appearance a well kept macadam road is.

After an extensive experience with macadamized roadways the writer does not favor "the stitch in time method of repairs," as it is much too costly. By this method is meant the keeping of piles of repair material at hand and having men patrolling the streets looking for broken places and immediately repairing them when found. A macadam road with very light traffic will wear one inch in a year and with heavy traffic will wear from two to three inches. An attempt to save this wear by continually placing little dabs of material in depressions is foolish. The least expensive and most satisfactory method is to pick down the edges of depressions and use the material to fill the low places with the addition at times of a very small amount of new stone. When the entire surface has worn down three or four inches then roughen it by some proper method and resurface the roadway with new material. This method simply contemplates that no deep holes and no ruts will be allowed to form. One man with a team can do as much work on the streets as half a dozen men with two or three teams under the "stitch in time" way. The street will always look as well, so the maintenance cost is reduced and as good results obtained.

Specifications are given for macadam roadways. If the ground surface is excavated one foot more and large stones on edge set closely together as a pavement foundation over the whole surface, before placing the macadam, we have a Telford road.

Dust is a nuisance on macadam roads, so it is customary to sprinkle them. The water assists in binding the materials together, at the same time it carries into the stone certain elements that combine to destroy and disintegrate it, for water is the greatest solvent in nature. The dry dust is ground between wheels and the hard surface and helps grind it up. When the dust is wet and in the form of thin mud this action is worse. For this reason it is good policy to keep the macadam as free from dust as possible. This is best done by an occasional scraping up of the dust and hauling it away. It should be sprinkled before being swept up, as it is more readily handled when wet. After all is hauled away that can be hauled, the street should be washed with a hose.

Considerable space has been devoted to macadam because it is so well known and such a present favorite with the majority of people. It is doomed, however, and in its present form will disappear probably within the present generation, except in out-of-the-

way places. The reason for this is the rapid increase in the number of automobiles and the high speeds at which they usually run. The suction of the rubber tires on gravel and macadam roads makes them go to pieces rapidly, and all over the world men are experimenting with different methods of making macadam roads more durable.

This is generally sought to be accomplished by coating the surface with some asphaltic or oily material. Westrumite, named after the inventor, Dr. Westrum, a German scientist, is an oily material which is placed in the tanks of sprinkling wagons and mixed with the water. It was invented for the purpose of allaying to some extent the sprinkling nuisance. It is largely used in Europe and has lately come into use in the United States. One round of the sprinkling carts with Westrumite seems to do more good than several rounds with plain water. As the liquid binds the surface and helps stop the formation of dust it is no doubt of considerable benefit on streets used by automobiles, although when first introduced the inventor had no thought of this. He simply wanted to lessen the formation of mud by sprinkling and make it unnecessary to sprinkle often.

In France experiments are being made with plain tar. It has been tried by placing it on dust covered roads, forming a coating of dust and tar and has been tried on roads thoroughly cleaned. It has also been put on cleaned roads loosened for a depth of a few inches and covered with an inch of sand and rolled after the tar has been added.

Tar is a material that stands extremes of temperature badly and is volatile to a degree. A road is apt to go to pieces if the tar gets too hard, and if anything is added to it to keep it soft it is apt to be disagreeable. The necessity, however, for doing something to improve macadam roads will be sure to lead to experiments of value. Tar is now comparatively cheap and not hard to obtain in some places, so it may be utilized largely for this purpose.

Several firms in the United States advertise tar for the above purpose and also for the construction of Tar Concrete and Tar Macadam roads, which we will touch upon later.

For some years oil has been used in California to lessen the

dust nuisance, which is almost unbearable during the long dry summer in that state. All grades of oil are used and the plan for country roads is simply to saturate the surface to a depth of a few inches to make it heavy, so the dust will not rise.

No attempt was made at first to make a smooth hard surface, as the men who first used the oil believed there should be at least an inch of loose material on top to incorporate with the oil. It was soon noticed that if the oil contained a heavy percentage of asphalt it improved the surface of the road. It was found, also, that as the surface improved the road was used for heavy teaming. The good surface being only a few inches thick soon went down into the insufficient foundation and the road became rutty. Today where oil is used it is either used as a thin oil frankly to save frequent sprinkling with water, or a very heavy oil is used in connection with macadam or gravel. This is the best way to use it.

ASPHALTED MACADAM.

The roadway then is of asphalted macadam. The macadam roadway must be built in accordance with the best specifications, with a good crown and very smooth surface. The macadam has to carry the loads. The asphalted surface simply takes all the wear and is a thin, slightly elastic covering for the base. Catch basins should not be used on the surface, for standing water softens it and it goes to pieces. If gutters are used they should be of stone or brick.

After the macadam base is put carefully down a thin layer not exceeding one-half inch of fine angular gravel or clean coarse sand is spread over it evenly and of the exact thickness required. Upon this is applied the liquid asphalt or heavy asphaltic oil at a temperature of not less than 150 degrees F. The quantity used varies from three-fifths to three-quarters of a gallon per square yard.

Special spreading and distributing machines are used for this work. After the first coat is applied it is allowed to stand without disturbance for twenty-four hours. Then a second thin layer is put on and covered with from two-fifths to one-half gallon of oil per square yard. This likewise stands for twenty-four hours or as long as the judgment of the experienced man in charge thinks is right. Then a thin coat of sand or fine gravel is put on for the purpose of absorbing the excess of oil. Some rolling with a light

roller is done to get the surface smooth and the street is thrown open to travel. If sticky parts develop they are filled with sand at once.

For several weeks after the street is completed it is a good idea to roll it frequently with a roller of at least ten tons to make and keep it smooth during the hardening process. The result is a smooth asphalt pavement obtained at a fraction of the cost of a regulation asphalt pavement. Sometimes the rolling is omitted altogether.

The liquid used to secure the best results has a gravity of about 10.5 degrees B, and contains over 80 per cent of "D" grade asphalt, over 90 per cent of asphaltum in liquid form. It is not so likely to be injured by the high degree of heat necessary to reduce asphalt to the hard form and takes longer than hardened asphalt to harden in use.

If asphalted macadam roads are built in states where a long, dry, warm season can not be depended on, the work should be done in a week when it is hot and rain is not to be expected. The macadam base should be warm and dry. Otherwise a good bond will not be secured and the covering will be inclined to peel off.

TAR CONCRETE ROADS.

Use tar containing not more than 5 per cent of water and not less than 50 per cent of pitch. Have the tar hot and the stones dry and warm. Use enough tar to coat all the stones and construct the roadway exactly like constructing a regular macadam road, but use the tar throughout in every layer.

TAR MACADAM ROADWAYS.

Roll the earth thoroughly, as for a macadam road. Spread over it a layer four to six inches thick of stones, like the lower layer of a macadam roadway. Roll this layer until it is solid and smooth.

The bottom layer contains no tar. Cover it with two or three inches of crusher run stone dried and warmed and mixed with hot tar, using from ten to twelve gallons of tar per cubic yard of stone. Spread this stone quickly and in an even thickness. Cover it with a half inch of coarse sand, fine gravel or rock dust and

roll. Little rolling is required. Throw it open to travel immediately.

ARMORED MACADAM.

Another form of macadam requires notice. Some years ago a German engineer propounded the theory that macadam roads went to pieces rapidly because the stones in the top layer differed so much in size that considerable movement occurred. Under constant rubbing the edges and angles gradually wore off and this made dust. The more dust the greater attendant wear because the dust has a grinding action.

Twelve or more years ago he built armored macadam roads that are said today to be in perfect condition under very heavy traffic. They are being experimented with in England at present. The subsurface is thoroughly rolled and the bottom four or six inches of the macadam roadway put in according to the usual specifications. This is solidly rolled, after which an inch of sand is placed over it. On top of the sand (and partly bedded in it) stones four inches deep and from three to five inches square are placed by hand as closely together as possible. Care is taken to have them as nearly cubical in shape as possible and as nearly the same size as possible. Fine dry sand is brushed into the close joints and the entire surface is covered with an inch or two of sand. This is wet and rolled in order that all the joints will be thoroughly filled. The appearance of the street is that of fine mosaic work.

An armored macadam roadway is excellent where automobiles are used to any extent.

BITULITHIC PAVEMENTS.

The satisfaction given by tar pavements during the first months after construction has led to the introduction of the bitulithic pavement. Unfortunately it is a patented pavement, so some ingenuity has to be exercised in drawing specifications permitting its use in competition with other materials.

The writer wishes to go upon record as saying that with honest workmanship and honest materials the bitulithic pavement in his opinion has a larger percentage of desirable qualities than any material he is acquainted with. It approaches very nearly the ideal pavement.

By making the above statement about the bitulithic pavement he is not to be understood as saying that it approaches the ideal pavement most closely for all places. Local considerations must never be neglected. It is in the abstract that the remark is made, considering that a city can make a free choice of all approved materials upon a practically equal basis. In a particular case wood may be ideal for one town, brick for another, macadam (in some one of its many forms) in another, etc.

So far as the writer has had an opportunity to judge, and he has seen the pavement in many cities, the bitulithic pavement possesses all the advantages of asphalt, with few of the disadvantages. Asphalt a few years ago was heralded as the ideal pavement under all conditions and for all places. Today it must take a second or lower place.

While the bitulithic pavement is in many respects similar to the tar macadam pavement, the great secret of its success lies in the density obtained by careful arrangement and proportioning of sizes of the crushed stone to fill the voids.

TARRING OF ROADS.

Since the appearance of the first edition of this book the Bureau of Road Inquiry, Washington, D. C., has issued pamphlets describing experiments made with tar treatment of roads, giving costs and results. These pamphlets are distributed free of cost by the government.

Tarvia is a preparation of tar which is prepared practically by boiling to remove all moisture and is used with great success for macadam road preservation.

WADSWORTH MACADAM.

This is essentially a roadway wherein a bituminous rock, found in Kentucky, is used as a binder and top coat for macadam roads.

PETROLITHIC PAVEMENTS.

These pavements are a California production and consist of oiled streets thoroughly tamped with the petrolithic, or Fitzgerald tamping roller.

Instead of simply rolling the treated surface this roller tamps the material for a depth of several inches. The illustration on page 55 shows the roller, and specifications for petrolithic pavements in the city of Los Angeles, Calif., are given at the end of this chapter.

The accompanying table of quantities of oil required for oiled roads can be used for estimating purposes.

COST IN CENTS OF GRAVEL PER SQ. FT. OF SURFACE AT VARIOUS PRICES PER CUBIC YARD AND SPREAD 1 IN. DEEP

Cost of Gravel	c70	c80	c90	$1.00	$1.10	$1.20	$1.25	$1.35	$1.45	$1.50	$1.55	$1.60	$1.65	$1.70	$1.75	$1.80	$1.85	$1.90	$2.00
Cost per Sq. Ft.	.216c	.247c	.278c	.309c	.340c	.370c	.386c	.417c	.448c	.463c	.478c	.493c	.508c	.523c	.538c	.553c	.568c	.583c	.598c

COST IN CENTS OF OIL PER SQ. FT. OF SURFACE AT VARIOUS PRICES PER BBL. AND QUANTITIES OF OIL PER SQ. YARD

Gals. per Sq. Yd. of Surface	c90	c95	$1.00	$1.05	$1.10	$1.15	$1.20	$1.25	$1.30	$1.35	$1.40	$1.45	$1.50	$1.55	$1.60	For each additional 5 cents add
1	.238	.251	.265	.278	.291	.304	.317	.330	.344	.357	.370	.384	.397	.410	.422	.012
1 1-2	.357	.377	.397	.417	.437	.457	.476	.496	.516	.536	.556	.575	.595	.615	.633	.020
2	.476	.503	.529	.556	.582	.608	.635	.662	.688	.714	.730	.767	.794	.820	.844	.026
2 1-2	.595	.628	.662	.695	.728	.760	.793	.826	.860	.893	.926	.959	.992	1.025	1.055	.033
3	.714	.754	.794	.834	.873	.913	.953	.993	1.031	1.071	1.111	1.150	1.190	1.220	1.266	.039
3 1-2	.834	.880	.926	.972	1.018	1.065	1.111	1.158	1.203	1.250	1.296	1.342	1.388	1.435	1.477	.046
4	.952	1.005	1.058	1.111	1.164	1.216	1.270	1.323	1.375	1.428	1.481	1.534	1.587	1.640	1.689	.053

LINEAR FEET OF STREET COVERED BY 1 CUB. YD. OF GRAVEL SPREAD 1 IN. DEEP ON VARIOUS WIDTHS OF ROADBED

Width of Roadbed	20ft.	22ft.	24ft.	26ft.	28ft.	30ft.	32ft.	34ft.	36ft.	38ft.	40ft.	42ft.	44ft.	46ft.	48ft.
Linear Ft. of St.	16.2	14.7	13.5	12.5	11.6	10.8	10.1	9.5	9.0	8.5	8.1	7.7	7.4	7.0	6.7

LINEAR FEET OF STREET COVERED BY 1 BBL. OF OIL WITH VARIOUS WIDTHS OF ROADBED AND QUANTITIES OF OIL PER SQ. YARD

Gals. per Sq. Yd. of Surface	WIDTH OF ROADBED														
	20ft.	22ft.	24ft.	26ft.	28ft.	30ft.	32ft.	34ft.	36ft.	38ft.	40ft.	42ft.	44ft.	46ft.	48ft.
1	18.9	17.2	15.75	14.5	13.5	12.6	11.8	11.1	10.50	9.95	9.45	9.00	8.60	8.22	7.88
1 1-2	12.6	11.5	10.5	9.70	9.00	8.40	7.88	7.42	7.00	6.64	6.30	6.00	5.73	5.48	5.25
2	9.45	8.60	7.88	7.27	6.75	6.30	5.91	5.56	5.25	4.97	4.72	4.50	4.30	4.11	3.94
2 1-2	7.56	6.88	6.30	5.81	5.40	5.04	4.73	4.45	4.20	3.98	3.78	3.60	3.44	3.29	3.15
3	6.30	5.73	5.25	4.85	4.50	4.20	3.94	3.70	3.50	3.32	3.15	3.00	2.86	2.74	2.62
3 1-2	5.40	4.91	4.50	4.15	3.86	3.60	3.38	3.18	3.00	2.84	2.70	2.57	2.45	2.35	2.25
4	4.72	4.30	3.94	3.64	3.37	3.15	2.95	2.78	2.62	2.49	2.36	2.25	2.15	2.05	1.97

COBBLES.

For streets having heavy travel cobbles were used until lately. They are an obsolete pavement but as inquiries are still made about them they deserve some notice in such a work as this.

Cobbles were egg shaped pieces of gravel varying in size from six inches in length and breadth to as much as ten inches. They were laid in a cushion of sand on a shaped street surface without any foundation and tamped into place with heavy tampers, then covered with sand or fine gravel, wet, and rolled. They made a noisy pavement not particularly easy nor at all pleasant to travel upon. The first cost was about the same as macadam but the life was twenty times as great. The interstices can not be cleaned. For this one reason cobble pavements are condemned everywhere as being unsightly, and dangerous as well to health.

STONE BLOCKS.

Granite blocks are durable and much better than cobbles, which in the process of evolution they followed. They are, or should be, cut regularly to shape and size and set as closely as possible to make the joints small and thus lessen noise and make them more healthful.

The question of healthfulness and noise has been met in late years by filling the joints with cement grout (which is apt to make the pavement slippery) or with an asphalt grout. The joints being filled the street can be easily kept clean. It was formerly the custom to lay them like cobbles on a bed of sand a few inches thick. It is no longer done, for the pavement never remained even. The foundation can never be too good, for it carries the load. The pavement is merely the wearing surface.

A concrete foundation should be never less than six inches thick and in some places where the earth is yielding it should be eight inches thick. This applies not only to granite blocks but to all modern pavements. Upon the top of the foundation should be a bed of fine sand an inch thick to take care of irregularity in the depths of the blocks and also to prevent the loose ones from hammering the foundation to pieces.

Stone blocks are peculiarly suitable for warehouse districts. When granite can not be readily obtained basalt is used. This stone, however, gets slippery in a short time. In some parts of the world there are varieties of sandstone which make beautiful pavements. Sandstone can be trimmed into more regular blocks than any other stone and the size of the joints thus decreased, without affecting the foothold much, while it does have a decidedly good effect in lessening noise and the cost of cleaning.

When a stone block pavement gets too slippery the tops of the blocks can be dressed with tools or the blocks can be taken up and relaid with the bottoms up. In fact the full wearing capacity of a stone block pavement is not reached until the blocks have been dressed once, then turned when the effect of the dressing has worn off, dressed on the turned end when that has worn smooth and then replaced with new blocks while the old ones can be crushed to be used in concrete or in a macadam road.

WOODEN PAVEMENTS.

Still following the line of evolution (in the attempts made to use local materials) we come to wooden pavements. This was tried and used after stone blocks proved to be suitable only in certain districts. As laid in various cities in different countries all over the world wooden pavements have been alternately praised and sworn at.

No doubt there are places where wooden pavements are used after having been down over twenty years and are giving satisfaction, while we all know places where pavements of this material have to be replaced every five or six years and in some places the life of a wooden pavement is only two or three years. Cedar block pavements have been tried in many cities in the United States and it is hoped they have vanished forever. It is hard for us to

understand today why there was such a craze, about twenty years ago, for them.

Cedar trees six to ten inches in diameter were cut into six-inch lengths and these blocks were used for paving. Sometimes they were laid in a bed of sand on the earth and sometimes on boards. Once in a while it was thought best to cover the boards with tar or asphalt and dip the blocks in the same material. Sometimes the planks were in two thickness, well covered with asphalt and spiked together. Occasionally a concrete base was used and sometimes the blocks were laid on an old macadam roadway.

The blocks were laid as closely together as possible and the interstices caused by the rounded form filled with gravel or sand. Then asphalt or tar was poured in as a filler. The whole idea was low first cost. While new they made a good ,pleasing pavement. They soon got old and rotted from the bottom as soon as moisture got at them.

Modern wooden pavements are made of rectangular blocks placed on a concrete foundation with as small joints as it is possible to make. It is now generally understood that a close grained wood must be used. Cedar has been a failure because too soft, although its lasting qualities in ordinary situations is well understood. A hard wood is not desirable because it gets too hard and smooth and after a little use the edges of the blocks become worn and it is filthy, slippery and noisy. The proper kind of wood then is one that is close grained and lies between the hard and soft classification.

It must be kiln dried (except in the case of California redwood) and protected from decay. The blocks should be about six inches long, three to four inches wide and about six inches deep, being set with the grain vertical.

Eucalyptus wood from Australia or California and California redwood can be used after drying, by simply dipping under a five foot head in hot asphalt and laying at once on the foundation, which should be covered with about one-half inch of sand. It is important that the blocks be coated on the bottom as well as on the tops and sides with asphalt.

Wooden pavements rot from the bottom. If the blocks have no asphalt on the bottom the moisture gets through after traffic has worn the top coating off and collects until it spreads over a

large area. When it reaches a porous block it attacks it. In this way two or three soft blocks can let enough water through to destroy yards of pavement. If the asphalt protects the blocks on the sides as well as on the bottom and the top each block is isolated and if water gets into it there is no danger of it going farther. When the storm is over capillary attraction will bring the water to the surface and the sun will evaporate it.

The writer has laid satisfactory pavements of Oregon woods and of ordinary pine with asphalt but believes it is better to inject creosote into such woods. Creosoted pavements are used in many places with satisfaction. Over the top of all wooden pavements should be placed a coating of hot asphalt and a half inch of sand or very fine gravel.

An expansion joint is necessary. The Australian method is to put a two or three-inch plank alongside the curbs and occasionally across the street. The blocks are laid as tightly as possible between these planks. When the blocks are all down the planks are taken out and the space filled with tamped clay. An American improvement has been to fill the space with asphalt. Thomas K. Muir, of Portland, Ore., patented a joint for wooden pavements, consisting of strips of canvas asphalted and covered with grated cork. This was laid between all joints across the street and helped the foothold on steep grades. In connection with this the usual method of putting planks along the curbs to be taken up and replaced with asphalt mixed with tar or sawdust was used.

The writer has a great fondness for a well laid, properly maintained wooden pavement, but of course understands that the first cost depends upon the source of supply; and the cost of maintenance is pretty high. It is an agreeable pavement and in sections of the country where the right material is readily obtained might easily be considered an ideal pavement, or, rather, be considered *the* ideal pavement.

Wooden pavements have given satisfaction for many years in Germany, France, England and Australia. In some cities wood is rated highest of all paving materials. Wherever competition permits the replacement of wood by brick, asphalt, etc., because of the cost, the wood pavements are going, except in particular localities.

A common mistake in the United States is to use wood only

on streets having light travel. It is almost impossible to have too much travel on a wood paved street. Experience has proven that heavy traffic is decidedly beneficial. It compresses the ends of the blocks and makes them durable. A wood paved street requires considerable water. It can not have too much. Alternate wetting and drying injure wood more than anything else. Frequent trips of the watering cart, enough to keep the pavement always moist, insures long life. Laid on a residence street with little or no traffic and never sprinkled a wood pavement will hardly last long enough for the property owner to pay the final assessment for its laying. Put on the street having the heaviest travel and kept continuously wet it vies with stone blocks in durability, besides being cleaner and not noisy.

The question of the unhealthfulness of wooden pavement is no longer raised. A modern wooden pavement is perfectly healthy. No harmful germs are ever found in the joints.

BITUMINOUS ROCK.

This material was used for many years in California until other paving materials could compete in price. Beds of sand impregnated with asphalt (bitumen) were quarried and the material simply heated enough to enable it to be laid in thin sheets over a proper foundation. It was then rolled until cold. In appearance it could not be told from an asphalt pavement. It is a fairly good material and in all respects but one the equal of asphalt. The one defect is that all beds of sand contain more or less loam and earth and decayed matter. Consequently the material is not uniform and when laid on streets goes to pieces irregularly. Some parts may last for years and parts last only a few months. As soon as good asphalt deposits in California were developed bituminous rock as a paving material was discredited.

ASPHALT.

The asphalt used in Europe for many years was an asphaltic limestone, or rather a limestone impregnated with asphalt. It was put on the street in the natural state, like bituminous rock, but made a slippery pavement. In wet weather it was necessary to sand it to keep horses from slipping. This slipperiness was a

great objection and asphalt did not grow in favor until the exploitation of the asphalt lake in Trinidad by American promoters and the formation of great asphalt paving companies.

It has grown in favor ever since and many other sources of supply are drawn upon. It is believed there is an asphalt trust that controls all known sources of supply.

The material is refined and brought to the street in barrels where it is softened by heat and mixed with sand and a filler of very fine material and laid on a good foundation while hot. Before it cools it is rolled to its final thickness with a heavy roller. It should be cheap if cost of material alone is considered, for only the asphalt is brought into the town. The rest of the material is local.

The mixture of asphalt, sand and other ingredients must be varied with the climate, grade of the street and innumerable other conditions. This calls for an amount of skilled supervision few small cities can command. This is a matter that demands careful thought on the part of the council. If the small place is bound to have an asphalt pavement without disinterested expert advice and guidance the authorities should be careful to award the contract to some very strong company under a maintenance guarantee for ten or fifteen years. The question of the maintenance bond is a legal one.

A properly laid and properly maintained asphalt pavement can not be too highly praised. It has serious defects, however. It is easily injured by oil (another argument involving the automobile), by leaking gas, by contraction and expansion, by standing water and excessive moisture and improper judgment as to the use of fluxes when laying. Asphalt then has its proper place in the large cities. If used in small places they should be close to large cities where it will not be difficult to get competent men to lay the pavement and look after it.

BRICK.

Brick pavements run asphalt very close. They also require a concrete base for reasons before mentioned. The use of brick is another case where local considerations are a large factor. The material from which vitrified paving brick are made can not be found in every section of the country. The "surface clays," known

to every brickmaker, can not be used successfully for this class of brick, the range of temperature at which they can be vitrified being very narrow by reason of too much silica or too much lime. So the brick will be either unburned and thus be soft or will be misshapen and can not be used. It is well to remember this when the local brickmaker pleads for a chance to burn brick for paving a street.

An impure fire clay generally known as "pipe clay" can be used for paving brick. These impure clays make tough paving brick when properly vitrified. As it requires a very high heat to vitrify them great care must be taken that the brick are not allowed to be soft.

The really proper material for paving brick is a shale found generally in the vicinity of coal measures and known as "soapstone" and also as "soft slate." These shales have to be ground up and mixed with water to make them plastic so they will mold satisfactorily.

It can readily be seen that if vitrified brick can not be made near the town it will be difficult to count on it as a paving material. The price in the middle, central and eastern States is from $5 to $8 per thousand, and in the western States from $15 to $25. At a price not to exceed $15 per thousand brick can compete with asphalt. If it has to be hauled any considerable distance the freight item kills all consideration of its use for paving. The cost is too great, for all the pavement is brought in, whereas with asphalt only about 10 per cent is foreign material, the rest being local. Bituminous rock and asphaltic limestone could not compete with asphalt as it constituted only about 10 per cent of the pavement, hence freight charges were low. The other two materials had to be brought in entire and freight charges were high.

Brick pavement is in every way as satisfactory as asphalt where tried side by side. There are enthusiastic supporters of each material.

If the first cost of the two materials is the same the writer prefers brick. The cost of maintenance is no higher for brick. It is practically as noiseless as asphalt and the clicking sound of horse shoes on it has seldom been mentioned as objectionable. If not properly put down there is apt to be a distressing rumble under continuous traffic but it is not a characteristic inseparable from

the use of the material. It should have expansion joints placed as described for wood pavements.

The great argument in favor of wood and of brick as against asphalt is that highly trained scientific supervision is not so necessary as with asphalt and there is no necessity for a complete reliance upon the honesty of the contractor in the absence of special expert advice.

Given proper specifications, a careful selection of material by an honest man of the most ordinary education, with honest supervision by men of little or no education but with common sense, and brick or wood pavements can compete successfully with any others.

The writer hopes the foregoing review of the materials in common use will assist in making a selection. The specifications given represent common practice but before doing any street paving with materials other than can be obtained near home further information is needed. The literature is extensive and up to date books are readily obtained.

The cost of pavements per square yard are given by Professor Baker as follows:

Gravel	$0.50
Macadam	0.75
Brick	1.75
Rectangular wood blocks	2.00
Sheet asphalt	2.75
Granite block	3.50

The above were obtained from larger cities than this little book is intended for. They are all averages.

CONCRETE.

In the following pages will be found specifications for concrete pavements. While a concrete base is necessary for modern pavements, a wearing surface has always been deemed necessary. Within the past twelve or fifteeen years, however, a number of concrete pavements have been put down.

Where good materials were used and care exercised the results have been good. Such a pavement possesses all the advantages of a granite block pavement at a lower cost. It has also an additional advantage over a granite block pavement in that it has

no joints and is therefore less noisy and more cleanly and healthy. It can also be more readily repaired if broken. It is a difficult street to tear up and all underground work should be done and the ground settled before it is laid.

HASSAM PAVEMENT.

This ingenious pavement, specifications for which are given at the end of this chapter, is practically a concreted macadam.

MAINTENANCE.

Every city should possess a road machine, crusher and road roller. Steam rollers are cheaper and better than horse rollers. The writer from his experience prefers comparatively light rollers that will travel rapidly. Seven tons is about right, although five tons have been used with success.

The following extract from the 1904 report of the state fire marshall of Ohio is interesting in so far as it relates to a proper regulation of pipe laying in streets:

"Fires reported to the state fire marshal during 1904 as being caused by gas explosion, gas leaks and by explosion, number ninety-four, but many fires reported as from unknown causes are doubtless properly chargeable to gas.

"Gas leakage under the impervious pavements of cities is a subtle, uncontrollable, menace to property and to life as well. Many mysterious conflagrations presenting inexplicable phenomena are due to the presence in houses of gas which has entered through the cellar from a leaking main.

"Gas companies anticipate a loss from leaks of 12 to 20 per cent of all the gas they force into the mains, it being cheaper to bear that loss than to open the streets and repair the pipes. A leakage of 187,000 cubic feet per mile per annum for four-inch mains is considered nominal. The report of the Massachusetts State Board of Gas and Electric Light Commissions showed that in 1899 the mains in use for gas distribution in that State averaged 4.81 inches in diameter and their leakage for the year was 162,334 cubic feet per mile. The gas companies of Massachusetts are required to report their 'gas unaccounted for' which elsewhere is considered a confidential fact.

"The authoritative tables of Field's Analysis of Gas Undertakings show that in the cities of England the gas leakage is about 500,000 cubic feet per mile of main per annum.

"In small towns this gas escapes harmlessly through the earth, except when the ground is frozen, but under the asphalt and stone pavements of the city it is at all times forced along the outside of the main until it finds a fill around a service pipe, which, by reason of its being more open, offers a path of least resistance into the cellar of some house. If the ventilation of the cellar is not ample the gas, being lighter than air, accumulates in coal vaults or between the joists, where an accidental spark, the striking of a match or the flame of a candle, will ignite it with or without explosion. If the amount of the escaping gas is large it may be found in layers next the ceiling of every story of the house."

SPECIFICATIONS.

The specifications given here are carefully chosen but there may be better ones produced each year. Before blindly copying make a search.

BRICK.

The following specifications were adopted for brick pavements at the Sixteenth Annual Convention of the National Brick Makers' Association:

SUB-STRUCTURE OR GRADE.

Earth in excavation to be removed with plow and scraper, or other device, to within two (2) inches of sub-grade, then brought to true grade with the roller, the weight of which should not be less than five (5) nor more than eight (8) tons. If the earth is too hard to receive compression through the weight of the roller, then loosen the remaining two (2) inches with a pick and cart away.

Earth in embankment must be applied in layers of eight (8) inches in thickness and each layer thoroughly rolled, and in both excavation and embankment the sub-grade must have a uniform density.

If the ground is a spouty clay, tile drainage should be provided to carry off this accumulation of wet.

CURBING.

If cement is used it should be completed, if stone, all should be hauled and distributed and set before the grading is finished, and may then be used as a guide to finish the sub-grade.

It should range in thickness from four (4) to six (6) inches, twenty (20) to twenty-four (24) inches deep, the business and street traffic governing the same, and lengths not shorter than five (5) feet, except at clos-

ures. Neatly dressed on top with a square or rounded outer edge and four (4) inches down on the inside. The outer surface to be tool dressed to the depth of the face exposed and to the depth of the thickness of the brick and sand cushion. The intersection at street corners and alleys should be circular, with radius of four (4) and three (3) feet, respectively.

(NOTE—In this connection the writer wishes to call attention to his remarks earlier in this book, on having a large radius at intersections.)

MARGINAL CURBS.

Should always be of a hard and durable character, of stone, and from fourteen (14) to eighteen (18) inches deep, dressed on top and five (5) inches down on the face next to the brick.

Set to accurately fit the curvature of the cross-section of the street, on six (6) inches of concrete and backed up with the same within six (6) inches of the top.

CONCRETE FOUNDATION—CRUSHED STONE.

Should be of approved quality of hard rock, with no fragment larger than will pass through a two (2) inch ring and none smaller than will pass through a one (1) inch ring in their longest dimensions, free from all refuse and foreign matter.

(NOTE—It will be seen from these specifications that a dense concrete is not called for. The stone is ranged between two sizes that will assure at least 30 per cent of voids. In the following paragraphs it will be seen that only half enough sand to fill the voids is called for. To get a dense concrete smaller sizes of stone should be permitted.)

SAND.

Must be clean, sharp and dry, and thoroughly mixed in its dry state until the whole mass shows an even shade, with an approved brand of either hydraulic or Portland cement. If of hydraulic, the proportion of mixture should be of one part of cement and two parts of sand; if of Portland cement, one part of cement and three parts of sand.

(NOTE—By hydraulic cement is meant natural cement, for Portland is also an hydraulic cement.—McC.)

To the above mixtures should be added sufficient clean water to mix to a plastic mass, fluid enough to rapidly subside when attempting to heap to a cone shape. To this mixture add four (4) and five (5) parts, respectively, of damp crushed stone, or clean, screened gravel, and turn the whole mass over not less than three (3) times, or until every fragment is thoroughly coated with the cement mixture. For the reception of this mixture the grade should be set off in five (5) foot squares, with a stake at each corner. Tops of each should be at the surface of the concrete, which must be tamped until free mortar appears at the surface. Occasional sprinkling in extreme hot, dry weather is beneficial. After thirty-six hours the cushion sand may be spread.

SAND CUSHION.

Sand should be clean and free from loamy matter. It need not necessarily be sharp. It should be two (2) inches thick before the compression of the brick by rolling. The sand should be spread by the aid of a tem-

plate, the whole or one-half the width of the street, made to conform with the true curvature of the street cross-section.

BRICK.

The brick should all be hauled and neatly piled inside of the curb line before the grading is finished, or, if allowed by the engineer, delivered on the street in wagons and carried from the pile or wagon on pallets or with clamps, and not wheeled with barrows. They should be first-class and thoroughly vitrified, showing at least one fairly straight face, with rounded edges, with no greater radius than 3-16 of an inch. They should not be less than 2½x4x8, or more than 3¼x4x9 inches, free from cracks, with but slight lamination and at least one edge with but slight kiln marks allowed.

Such brick or blocks shall be submitted to a test of an hour in the National Brick Manufacturers' Associations' standard rattler, and under the conditions prescribed by that association, and if the loss by abrasion during such test exceeds 20 per cent of the original weight of the brick tested, then such brick or blocks shall be rejected.

BRICK LAYING.

Brick should be laid perpendicular to the curb. Broken brick or block can only be used to break joints in starting courses, or in making closures. The brick shall be laid on edge, close together, in straight lines across the roadway between gutters. Gutters shall be constructed as directed by the engineer. After the brick are laid they shall be thoroughly inspected and all warped, spalled and soft brick removed and replaced by more perfect ones, and those found with the bad face up should be turned down.

TAMPING AND ROLLING.

After the inspection is thus completed the edge of the pavement shall be tamped to grade next to the curb, to the width of six (6) or eight (8) inches out from the curb, with a hand tamper. The entire pavement shall then be rolled with a five (5) ton steam roller until all brick are thoroughly bedded and the whole surface assumes a practical plane conforming to the gradient and curvature of the roadway.

EXPANSION CUSHION.

An expansion cushion must be provided for, one inch thickness next to the curb, filled two-thirds its depth with pitch, the top third being filled with sand and a like cushion at right angles with the street, at intervals of fifty feet.

THE FILLER.

The filler shall be composed of one part each of clean, sharp sand and Portland cement. The sand should be dry. The mixture, not exceeding one-third bushel of the sand, together with a like amount of cement, shall be placed in the box and mixed dry, until the mass assumes an even and unbroken shade. Then water shall be added, forming a liquid mixture of the consistency of thin cream.

From the time the water is applied until the last drop is removed and floated into the joints of the brick pavement, the same must be kept in constant motion.

The mixture shall be removed from the box to the street surface with a scoop shovel, all the while being stirred in the box as the same is being thus emptied. The box for this purpose shall be 3½ to 4 feet long, 27 to 30 inches wide and 14 inches deep, resting on legs of different lengths, so that the mixture will readily float to the lower corner of the box, which should be from 8 to 10 inches above the pavement.

This mixture, from the moment it touches the brick, shall be thoroughly swept into all the joints. Two such boxes sha'l be provided in case the street is twenty feet or less in width; exceeding twenty feet in width three boxes should be used.

The work of filling should be thus carried forward in line until an advance of from fifteen to twenty yards has been made, when the same force and appliances shall be turned back and cover the same space in like manner, except that the mixture for the second coating may be slightly thicker than the first.

To avoid a possibility of too great thickening at any point, there should be a man with a large sprinkling can, the head perforated with small holes, splinkling gently the surface ahead of the sweepers. This should be done in the application of each course here specified.

After the joints are thus filled flush with the top of the bricks and sufficient time for evaporation has taken place, so that the coating of sand will not absorb any of the mixture, one-half inch of sand shall be spread over the whole surface. and in case the work is subjected to a hot summer sun an occasional sprinkling, sufficient to dampen the sand, shall be followed for two or three days.

The grouting thus finished must remain absolutely free from disturbance or traffic of any kind for a period of ten days.

WOOD.

Wood paving specifications, Brooklyn, N. Y.:

1.—The wearing surface shall be composed of longleaf, all heart, yellow pine blocks, treated as hereinafter described. All blocks sha'l be of sound timber, free from bark, sapwood, loose or rotten knots, or other defects which shall be detrimental to the life of the block or interfere with its laying. No second growth timber will be allowed.

2.—The blocks are to be treated throughout with an antiseptic and waterproof mixture, at least 50 per cent of which shall be dead oil of coal tar, commonly known as creosote oil. The remainder to be resin or some other similar and suitable waterproof material. All portions of each individual block shall be thoroughly treated with the mixture, and after treatment the specific gravity of the blocks shall be greater than that of water.

3.—After treatment the blocks sha'l show such waterproof qualities that, after being dried in an oven at a temperature of 100° for a period of 24 hours, weighed, and then immersed in clear water for a period of 24 hours and weighed, the gain in weight shall not be greater than 3 per cent.

CHICAGO SPECIFICATIONS.

The following paving specifications were in use in Chicago during 1905:

CURB STONE.

The curb stone must be of the best quality of .... stone, straight and free from cracks, seams, sand pockets or drill holes. Buff-colored sandstone will be rejected.

The top edge must be of full thickness, square, and neatly bush-hammered. The face must likewise be dressed to a depth of twelve (12") inches from the top. The back side of the stone must be "pointed" to a depth of at least two (2") inches so as to leave the top of the stone five (5") inches in thickness throughout. The ends shall be dressed smooth and square to a depth of eighteen (18") inches from the top, so as to make close joints. The bottom of the stone must be straight and parallel with the top.

Where sandstone is used the upper roadway corner shall be rounded to a radius of one and one-half (1½") inches.

The stones, after being dressed, shall be not less than five (5") inches thick, three (3') feet deep or four (4') feet long. In no case shall the lengths of the stone on the top and bottom differ by more than one (1') foot.

The curb stone shall be set to the established grade in a continuous line on each side of the street, ... feet from and parallel with the center line thereof, except at all intersections of streets and alleys, where the curb shall be returned to the street line. All grades and lines will be given by the Engineer. The stones are to be firmly set upon blocks of flat stone six (6") inches in thickness, and at least eight by twelve (8"x12") inches in size. Oolitic limestone and sandstone shall not be used for blocking.

At each street intersection there shall be furnished and set four (4) and at each half intersection two (2) circular corner stones cut to a radius of two (2') feet, unless otherwise ordered by the Engineer. These stones must be bush-hammered on top, and on the face for a distance of eighteen (18") inches down. No extra charge will be allowed for circular corner stones.

All curb stone now set on the street, that is not at the proper line or grade, must be placed in proper position.

The curbing shall be back-filled to the top, and the filling at that point shall be four (4') feet wide and shall have a slope of one and one-half (1½) horizontal to one (1) vertical. The full quantity of filling shall be put in front and back of each curb stone as it is set, and must be thoroughly rammed with a proper rammer at the same time, so that the curbing will be firmly held in place.

No lines or grades will be given for the setting of curb stones until the same shall be dressed according to specifications.

COMBINED CURB AND GUTTER.

In making the combined curb and gutter Portland cement shall be used and ordinarily will be subjected to the following inspection and tests:

(NOTE—The writer advises here the Standard Cement Specifications, Chapter X, instead of those used in Chicago.)

Samples of cement which it is proposed to use in the work shall be sub-

mitted to the Board of Local Improvements in such quantities and such time and place as to make all the required tests.

The Board of Local Improvements reserves the right to reject, without recourse, any cement which is not satisfactory, whether for reasons mentioned in these specifications or for any good and sufficient cause.

All cement to be used in the combined curb and gutter must be delivered on the work in approved packages bearing the name, brand or stamp of the manufacturer. It shall be thoroughly protected from the weather until used, in such manner as may be directed.

The granite screenings used in making the concrete shall be clean, dry, free from dust, loam and dirt, and when delivered on the street shall be deposited on a flooring, and kept clean until used.

The crushed granite shall be clean, free from dust and dirt, broken so as to measure not more than one (1") inch in any dimension, and when delivered on the street shall be deposited on a flooring, and kept clean until used.

The granite concrete combined curb and gutter shall be constructed at the established grade and in a continuous line on each side of the street .... (') feet from and parallel with the center line thereof, except at all intersections of streets and alleys, where it shall be returned to the street line, and at such intersections there shall be formed the necessary circular stones built to such radii as the Engineer may direct. All grades and lines will be given by the Engineer. The combined curb and gutter shall rest on a foundation of cinders which must be six (6") inches in thickness after being thoroughly flooded and compactly rammed to an even surface.

The curb and gutter shall be made of concrete formed by intimately mixing one (1) part of cement with two (2) parts of fine granite screenings; to this mixture shall be added four (4) parts of crushed granite and the whole thoroughly mixed together, after which just sufficient water to wet the mass shall be added, so that when it is rammed in place a film of moisture shall appear on top. All exposed surfaces shall be covered with a finishing coat of mortar three-eighths (⅜") inch in thickness, composed of one (1) part of cement thoroughly mixed with one and one-half (1½) parts of the fine granite screenings. Before the concrete sets the curb and gutter shall be cut into sections not exceeding six (6) feet in length.

The gutter flag must be eighteen (18") inches wide and five (5") inches thick; the curb must be seven (7") inches thick throughout, except at the upper face corner, which is to be rounded to a radius of one and one-half (1½") inches. The height of the curb above the gutter flags will be of varying dimensions, averaging not less than ...... (") inches.

The contractor or contractors shall build without extra charge all "inlets" necessary to properly connect the combined curb and gutter with the catch-basins, and such steps on the gutter flags at the crossings as the Engineer may direct.

The curb and gutter shall be back-filled to the top, and filling at that point shall be four (4') feet wide and shall have a slope of one and one-half (1½) horizontal to one (1) vertical. The full quantity of filling shall be put in front and back of each section of curb and gutter as it is built, and must be thoroughly rammed with a proper rammer at the same time so that the curb and gutter will be firmly held in place.

CURB WALL REPAIRS.

Wherever curb walls on the line of this improvement are found to be defective, they must be torn down and rebuilt to such a depth from the top as the Engineer may direct. In this rebuilding the contractor or contractors will be allowed to use all the old material previously therein contained which may be suitable, but must also furnish any and all new materials which may be necessary to bring the wall to the line and grade given by the Engineer, and finish it in a good and workmanlike manner.

The roadway side of the wall to a depth of .... (') feet from the top of the masonry shall be plasteered at least one-half (½") inch thick with a mortar composed of one (1) part of approved Portland cement and two (2) parts of clean, coarse, sharp sand; the sand and cement to be first thoroughly mixed dry and then sufficiently moistened with water to form a thick mortar. The mortar must be used immediately after mixing, and no mortar which has once set shall be used.

The price bid per lineal foot of curb wall repairing and plastering must include all costs of the removal and replacing of cap planks, sidewalks, lamp posts, etc., and all necessary earth excavation.

PREPARATION OF SUB-GRADE.

Where filling is required it shall be of earth or cinders, free from animal or vegetable matter, and shall be deposited in layers of not more than two (2') feet in thickness, and shall be thoroughly compacted.

All necessary filling to bring the street to sub-grade and to properly back-fill the curb, shall be deposited on the street before any curb is set.

In all cases where curb is set the back-filling shall have a berme of at least four (4') feet behind the curb, at the top thereof, with a slope of one and one-half (1½) horizontal to one (1) vertical.

Where cutting is required the earth must be excavated to such depths as may be necessary to bring the roadway to the proper sub-grade after having been thoroughly compacted.

The earth shall be excavated back of the curb for a distance of four (4') feet level therewith; otherwise the contractor or contractors will not be allowed to remove the earth from the sidewalk area.

The contractor or contractors shall remove all spongy material or other inferior or vegetable matter that may be in the way of making this improvement.

All approaches connecting said street with other streets or alleys intersecting shall also be cut and filled so that the same shall have a slope of not less than one (1') foot in twenty (20') feet, and shall be secured from settlement adjoining the pavement.

The roadway shall be brought to sub-grade by cutting or filling as may be necessary; said sub-grade shall be eleven (11") inches below and parallel with the top of the finished pavement after having been thoroughly compacted and secured from further settlement by flooding, ramming, or rolling, or all, as may be deemed necessary by the Engineer.

The contractor or contractors will bid with the express understanding that he or they must use all necessary precaution in preparing the sub-grade so

as to support the pavement permanently, and so that the pavement shall remain at the original grade for a period of ten (10) years. This clause will not be waived on account of any trenches or holes made in the street prior to the laying of the pavement by any corporation or private party.

The price bid for cutting or filling must include all cost of bringing the sub-grade to its proper position and compacting and securing the same from settlement.

(To the above point the specifications are the same for all pavements.)

MACADAM.

CRUSHED STONE.

All crushed stone used in this improvement shall be the best of its kind, dry, clean, free from dust and dirt, and shall be practically uniform as to sizes and quality, and as near to a cube in form as possible.

MACADAM.

On the sub-grade as formed and compacted, shall be spread a layer of crushed limestone broken so as to measure not more than four (4″) inches and not less than two and one-half (2½″) inches in any dimension. This layer shall be covered with limestone screenings, in such quantity as to completely fill all interstices, then flooded and rolled with a ten (10) ton steam roller until thoroughly compacted. This layer shall not be less than .... (″) inches in depth at the center and not less than .... (″) inches in depth at the sides.

The above shall be covered with a layer of *medium* limestone broken so as to measure not more than two and one-half (2½″) inches and not less than one and one-half (1½″) inches in any dimension. This layer shall be covered with limestone screenings in such quantity as to completely fill all interstices, then flooded and rolled with a ten (10) ton steam roller until thoroughly compacted and brought to a true and uniform surface. This layer shall be not less than four (4″) inches in depth at the center and not less than two (2″) inches in depth at the sides.

The above shall be covered with a course of crushed granite broken so as to measure not more than two (2″) inches and not less than one and one-half (1½″) inches in any dimension. This course shall be covered with bonding gravel of such quality as may be approved by the Board of Local Improvements, and in such quantity as to completely fill all interstices, then thoroughly flooded and rolled with a ten (10) ton steam roller. On this layer shall be spread one-half (½″) inch of granite screenings which shall be rolled into said layer. The above layer shall not be less than four (4″) inches in depth at the center and not less than two (2″) inches in depth at the sides, after having been brought to a true, uniform and unyielding surface.

Each course above specified shall be built continuously and the stone for the same shall be spread immediately on being dumped.

In no case shall depressions be brought up with screenings.

The surface of the pavement shall be built to conform to the lines and grades furnished by the Engineer.

CROSSWALKS.

In the macadam pavement as above described crosswalks six (6') feet in width, extending from curb line to curb line, shall be built of vitrified shale paving brick; there shall be four (4) crosswalks at each street intersection, two (2) at each half intersection and one (1) across each intersecting alley wing.

The brick shall be true and uniform, five (5") inches in depth, from three to four (3" to 4") inches in width and from nine to twelve (9" to 12") inches in length. They shall be laid on a bed of one (1") inch of sand, so as to break joints, and in parallel courses. The spaces between the ends and sides of the brick must not exceed one-eighth (⅛") inch, and shall be filled with clean, sharp sand, and the brick rammed to a true and uniform surface. No broken or cracked brick will be allowed to remain in the crosswalks.

Where ordered by the Engineer a header composed of sandstone curbing four (4") inches thick by twenty-four (24") inches in depth, and of the required length, shall be set at the ends of the crosswalks in such position as directed.

The crosswalks, gutters and their appurtenances shall be formed and constructed where and as directed by the Engineer, and without extra cost over and above the price paid per square yard for the pavement.

(If some other material is to be used instead of macadam omit all under the headings, Crushed Stone, Macadam, and Crosswalks, and substitute the following specifications for concrete foundations, etc.:)

CONCRETE FOUNDATION.

On the sub-grade as above prepared shall be laid a foundation of Portland cement concrete to a uniform thickness of six (6") inches.

CEMENT.

(NOTE—Previously given.)

SAND.

The sand used in making the concrete shall be clean, dry, free from dust, loam and dirt, of sizes ranging from one eighth (⅛") inch down to the finest, and in such proportion that the voids as determined by saturation shall not exceed thirty-three (33) per cent of the entire volume, and it shall weigh not less than one hundred (100) pounds per cubic foot.

No wind-drifted sand shall be used.

The sand when delivered on the street shall be deposited on flooring and kept clean until used.

CRUSHED STONE.

The crushed stone used in making the concrete shall be of the best quality of limestone, clean, free from dirt, broken so as to measure not more than two (2") inches and not less than one (1") inch in any dimension.

The stone when delivered on the street shall be deposited on flooring and kept clean until used.

MIXING AND LAYING OF CONCRETE.

The concrete shall be mixed on movable tight iron platforms of such size as shall accommodate the manipulations hereinafter specified.

The cement, sand and stone shall be mixed in the following proportions: One (1) part of cement, three (3) parts of sand and seven (7) parts of crushed stone. The sand and cement shall be thoroughly mixed dry, to which sufficient water shall be added and then made into a stiff mortar. The crushed stone shall then be immediately incorporated in the mortar and the mass thoroughly mixed, adding water from time to time as the mixing progresses, until each particle of stone is covered with mortar.

The concrete shall be removed from the platform with shovels and deposited in a layer on the roadway in such quantities that after being rammed in place it shall be of the required thickness and the upper surface shall be true and smooth and ....(") inches below and parallel with the top of the finished pavement.

During the progress of the work the sub-grade must be kept moist.

The concrete shall be sprinkled so as to prevent checking in hot weather, and shall be protected from injury at all times, and shall lay at least seven days before being covered with the wearing surface, or a longer time if deemed necessary.

(The foregoing specifications for sub-base and foundation apply for all classes of wearing surface. From this point they are as follows for the different materials:)

ASPHALT.

ASPHALTIC CEMENT.

The asphaltic cement hereinafter specified shall be made of refined Trinidad Lake Asphalt, obtained from the island of Trinidad, or of an asphalt of equal quality for paving purposes, and heavy petroleum oil. The oil shall be mixed with the asphalt in such proportions as are suitable to the character of the asphalt used.

BINDER COURSE.

Upon the concrete foundation as above specified, shall be laid a "binder" course, composed of clean broken limestone of a size known as "small concrete," and asphaltic cement. The stone shall be heated and thoroughly mixed with asphaltic cement in the proportion of fifteen (15) gallons of asphaltic cement to one (1) cubic yard of stone, the mixing shall be continued until each particle of stone is thoroughly coated with the asphaltic cement. The binder shall be spread on the base above described, and, while in a hot and plastic condition, shall be rolled with a five (5) ton steam roller until it has a uniform thickness of one and one-half (1½") inches. The upper surface shall be parallel with and two (2") inches below the final surface of the pavement.

Binder that has been burned or has become chilled shall be removed from the line of the work.

WEARING SURFACE.

Upon this binder course shall be laid a wearing surface, which shall be composed of asphaltic cement seventeen (17) parts, sand seventy-three (73) parts, and pulverized carbonate of lime ten (10) parts. The sand and asphaltic cement shall be heated separately to a temperature of three

hundred (300°) degrees Fahrenheit. The pulverized carbonate of lime shall be mixed with the sand, and these ingredients then mixed with the asphaltic cement at the above temperature, in an apparatus which shall effect a perfect mixture.

The mixture at a temperature of not less than two hundred and fifty (250°) degrees Fahrenheit shall then be carefully spread by means of hot iron rakes in such a manner as to give a uniform and regular grade, and to such a depth that after having received its ultimate compression it will have a thickness of two (2″) inches. The surface shall be compressed by rollers, after which a small amount of hydraulic cement shall be swept over it, and it shall then be thoroughly compressed by a fifteen (15) ton steam roller; the rolling being continued as long as it makes an impression on the surface.

Where necessary to make the gutters impervious to water, a width of twelve (12″) inches next to the curb shall be coated with hot pure asphalt, and smoothed with hot smoothing irons in order to saturate the pavement with excess of asphalt.

WOOD.

SAND CUSHION.

Upon the concrete foundation shall be spread a layer of sand in such quantity as to insure, when compacted, a uniform thickness of one (1″) inch.

On surfacing said layer of sand the contractor or contractors shall use such guides and templets as the Engineer may direct.

WEARING SURFACE.

Upon the sand cushion as above specified shall be placed blocks of southern long leaf yellow pine. The blocks shall be four (4″) inches in depth and four (4″) inches in width, and shall not be less than five (5″) inches nor more than ten (10″) inches in length, with the fiber of the wood running in the direction of the depth. The blocks shall be made of sound timber and shall be square-edged, free from bark, shakes, loose or rotten knots, red heart or dead timber, and other defects which will interfere with the proper laying of the same. No second growth timber will be accepted.

After the blocks have been inspected and found satisfactory, they shall be placed in an air-tight chamber where, by means of superheated steam and the use of the vacuum pump the sap in the blocks shall be vaporized and the moisture in them removed. When the blocks are thoroughly dry the wood preserving oil shall be admitted into the chamber and subjected to a pressure which shall be maintained until twelve (12) pounds of the oil shall have been forced into each cubic foot of timber and until the oil shall have impregnated the timber through the entire depth of the block and to the satisfaction of the Board of Local Improvements. The wood-preserving oil shall be Kreodone-Creosote paving oil, or any creosote paving oil which shall in the opinion of the Board of Local Improvements be equal thereto in quality for this purpose.

The blocks shall be laid in parallel courses across the roadway at an angle of 45° with the center line thereof, except on alley wings where they

shall be laid perpendicular to the center line thereof. The courses shall break joints alternately. The blocks must be driven tightly together. Unless otherwise provided gutters shall be formed by setting four courses of blocks adjacent to the curbs and parallel thereto. Spaces for expansion shall be constructed as follows: The joints running parallel with and at the gutters shall be one (1") inch in width, and at intervals of one hundred (100") feet along the roadway the joint running across the same shall be one-half (½") inch in width. These expansion joints shall be filled with bituminous cement.

The blocks shall be firmly bedded in the cushion of sand and the surface of pavement brought to a uniform contour in accordance with the profile of the Engineer by rolling them with a five (5) ton asphalt roller.

The joints shall be filled with bituminous cement or pitch which will resist the solvent action of the wood-preserving oil, and which will not be brittle at 0° F., nor flow at 200° F. The cement shall be applied at a temperature of not less than 300° F., or at a higher temperature if necessary to render it fluid enough to properly run into and fill the joints. The blocks must be thoroughly dry before the cement is applied. Extra care must be taken and extra material must be used at the gutters and around catch-basins, manholes, etc., in filling all joints in both the paving and along the curbing to effectually prevent the leakage of water into the sub-roadway.

The contractor or contractors shall provide the Board of Local Improvements, or its representative, with a duplicate delivery ticket for each and every barrel, load or tank of paving cement delivered on the work. This ticket must be signed by the consignor of the cement, and be of a form approved by the Board of Local Improvements.

Immediately after the spreading of the paving cement, and while it is still hot, the same shall be covered to a depth of not less than one-quarter (¼") of an inch with clean, dry torpedo sand.

The cementing and top dressing must be completed each day to within twenty-five (25') feet of the face of the blocking.

If the blocks that have been laid should become wet before being cemented or top-dressed, they must be taken up and reset, without compensation therefor, should the Engineer so direct.

On streets having curbwalls the space between the walls and the blocks shall be filled with a mortar composed of one (1) part Portland cement and three (3) parts of clean, coarse, sharp sand.

HEADERS.

At the end of each intersecting street and alley wing there shall be placed a "Header," extending from curb to curb, and so dressed as to conform to the crown of the pavement. The "Header" shall be constructed of three by twelve (3"x12") inch oak plank, properly supported by six (6") inch split cedar posts, three (3') feet in length, firmly set in the ground and spaced not more than five (5') feet apart.

All "Headers" shall be constructed by the contractor or contractors without extra charge.

CROSSWALKS.

Unless otherwise directed by the Engineer there shall be formed in the

pavement four (4) crosswalks at each street intersection, three (3) at each half intersection and one (1) near the middle of each long block. A gutter nine (9″) inches in the clear width shall be constructed at the ends of the crosswalks by setting sandstone curbing in the roadway nine (9″) inches from and parallel with the curb line. The sandstone curbing must be four (4″) inches thick and twenty-four (24″) inches deep, and the length of the curbing shall be within three (3′) feet of the width of the abutting sidewalk space; provided, however, that the minimum length of said curbing shall be six (6′) feet.

The crosswalks, gutters and their appurtenances shall be formed and constructed where and as directed by the Engineer, and without extra cost over and above the price paid per square yard for the pavement.

BRICK.

SAND CUSHION.

Upon the concrete foundation shall be spread a layer of sand in such quantity as to insure, when compacted, a uniform thickness of one (1″) inch.

On surfacing said layer of sand the contractor or contractors shall use such guides and templets as the Engineer may direct.

WEARING SURFACE.

Upon the layer of sand as above specified shall be placed the brick of such quality and in such manner as hereinafter specified.

QUALITY OF BRICKS.

The brick to be used shall be of the best quality of vitrified paving brick. Salt glazed bricks will not be received.

The dimensions of the brick used shall be the same throughout the entire work in any particular case, and shall be not less than eight (8) inches in length, four (4) inches in depth, and two and one-half (2½) inches in thickness, with rounded edges to a radius of one-quarter (¼) of an inch.

Said brick shall be of a kind known as repressed vitrified paving brick and shall be repressed to the extent that the maximum amount of material is forced into them. They shall be free from lime and other impurities, shall be as nearly uniform in every respect as possible, shall be burned so as to secure the maximum hardness, so annealed as to reach the ultimate degree of toughness and thoroughly vitrified so as to make a homogeneous mass.

The bricks shall be free from all laminations caused by the process of manufacture, and free from fire cracks or checks of more than superficial character or extent.

Any firm, person or corporation bidding for the work to be done shall furnish specimen brick, which shall be submitted to a "water absorption" test, and if such brick show a water absorption exceeding three (3) per cent of their weight when dry, the bid of the person, firm or corporation so furnishing the same shall be rejected. Such "water absorption" test shall be made by the Board of Local Improvements of the City of Chicago in the following manner, to-wit: Not less than three (3) bricks shall be broken across, thoroughly dried, and then immersed in water for seventy-two (72) hours. The

absorption shall then be determined by the difference between the weight dry and the weight at the expiration of said seventy-two (72) hours.

Twenty or more specimen bricks shall also be furnished by each bidder for submission to the "abrasion" test by the Board of Local Improvements. Such test shall be made in the following manner, to-wit: Such specimen brick or a sufficient number to fill fifteen (15) per cent of the volume of the rattler shall be submitted to a test for one hour in the machine known as the "Rattler," which shall measure twenty (20) inches in length and twenty-eight (28) inches in diameter, inside measurement, and shall be revolved at the rate of thirty (30) revolutions per minute. If the loss of weight by abrasion during such test shall exceed twenty (20) per cent of the original weight of the brick tested, then such bid shall be rejected.

All brick shall have a specific gravity of not less than two and one-tenth (2.10) as determined by the formula—Specific gravity equals $\frac{W}{W'W''}$ where W equals weight of brick dry, W′ equals weight of brick after being immersed in water for seventy-two (72) hours, and W″ equals weight of brick in water.

All brick used must be equal in every respect to the specimen submitted by the bidders to the Board of Local Improvements for test.

HOW LAID.

All brick shall be delivered on the work in barrows, and in no case will teams be allowed on the street before the wearing surface is rolled.

Broken bricks can only be used to break joints in starting courses and in making closures, but in no case shall less than half a brick be used.

The bricks shall be laid on edge, close together, in straight lines across the roadway, between gutters, and at right angles to the curbs and perpendicular to the grade of the street. Gutters shall be constructed as directed by the Engineer.

The joints shall be broken by a lap of not less than three (3″) inches.

On intersections and junctions of lateral streets the bricks shall be laid at an angle of forty-five (45°) degrees with the line of the street unless otherwise ordered by the Engineer.

The bricks when set shall be rolled with a roller weighing not less than five (5) tons until the bricks are well settled and made firm. Or, if the Engineer shall direct, the bricks, when set, shall be thoroughly rammed two or more times. The ramming to be done under a flatter, with a paving rammer weighing not less than thirty (30) pounds, the iron of the rammer face in no case to come in contact with the pavement.

After rolling and ramming, all broken brick found in the pavement must at once be removed and replaced by sound and perfect brick.

PITCHING OR GROUTING AND TOP DRESSING.

When the brick are thoroughly bedded, the surface of the pavement must be true for grade and crown. The surface of the pavement shall then be swept clean, and the joints or spaces between the brick shall be completely filled with a paving pitch which is the direct result of the distillation of

"straight run" coal tar, and of such quality and consistency as shall be approved by the Board of Local Improvements. The pitch must be used at a temperature of not less than 280 degrees Fahrenheit.

When the brick are thoroughly bedded, the surface of the pavement must be true for grade and crown. The surface of the pavement shall then be swept clean, and the joints or spaces between the bricks shall be filled with a cement grout filter composed of limestone 65 per cent, furnace slag 25 per cent, and potters' clay 10 per cent, to be made as follows: The above materials in the proportion stated shall be mixed together and ground into an impalpable powder, and then burned in kilns unttil reduced to clinker, after which it shall again be ground into an impalpable powder. Equal portions of said grout and clean, sharp sand shall then be thoroughly mixed, and sufficient water added to bring the mixture to such a consistency as will allow it to run to the bottom of the joints between the brick. After said joints are filled to the top, the surface shall be finished off smoothly with steel brooms.

After the spaces between the brick have been filled with the pitch or grout as above specified, the surface of the pavement shall then receive a one-half (½") inch dressing of sand evenly spread over the whole surface.

Where cement grout is used as a filler the pavement must be kept clear of traffic for a period of four (4) days—or as much longer as the Engineer may direct—after the application thereof.

HEADERS.

At the end of each intersecting street and alley wing there shall be placed a "Header," extending from curb to curb, and so dressed as to conform to the crown of the pavement. The "Header" shall be constructed of three by twelve (3"x12") inch oak plank, properly supported by six (6") inch split cedar posts, three (3') feet in length, firmly set in the ground and spaced not more than five (5') feet apart.

All "Headers" shall be constructed by the contractor or contractors without extra charge.

CROSSWALKS.

Unless otherwise directed by the Engineer there shall be formed in the pavement four (4) crosswalks at each street intersection, three (3) at each half intersection and one (1) near the middle of each long block. A gutter nine (9") inches in the clear width shall be constructed at the ends of the crosswalks by setting sandstone curbing in the roadway nine (9") inches from and parallel with the curb line. The sandstone curbing must be four (4") inches thick and twenty-four (24") inches deep, and the length of the curbing shall be within two (2) feet of the width of the abutting sidewalk space; provided, however, that the minimum length of said curbing shall be six (6') feet.

The crosswalks, gutters and their appurtenances shall be formed and constructed where and as directed by the Engineer, and without extra cost over and above the price paid per square yard for the pavement.

GRANITE BLOCKS.

SAND CUSHION.

Upon the concrete foundation shall be spread a layer of sand in such quantity as to insure, when compacted, a uniform thickness of two (2") inches.

On surfacing said layer of sand the contractor or contractors shall use such guides and templets as the Engineer may direct.

GRANITE BLOCK.

Upon the sand cushion shall be set syenite or granite paving blocks having a uniform grain and texture, without lamination or stratification, and free from an excess of mica or feldspar.

The blocks shall measure from three and one half (3½") to four (4") inches in width, eight (8") to ten (10") inches in length, and five (5") inches in depth, and be so dressed as to have substantially rectangular plane surfaces, so that when the blocks are in place the joints at the ends and sides shall average one-fourth (¼") inch in width. Soft or weatherworn stones obtained from the surface of the quarry, and stones which wear to a polish under traffic, shall not be used.

The blocks shall be laid in uniform courses across the roadway between the gutters (except at the intersections of the streets where they shall be laid at an angle of forty-five (45°) degrees with the center line thereof) and the space between the blocks, when in place, shall in no case be less than one-eighth (⅛") inch nor more than three-eighths (⅜") inch. Each course shall consist of blocks of the same width, and be so laid that all longitudinal joints shall be broken by a lap of at least three (3") inches. The gutters shall be formed as directed by the Engineer.

The spaces shall be immediately filled to within two (2") inches of the top of the blocks with dry gravel free from loam and dirt, and the blocks rammed to a true surface and firm bed with a seventy-five (75) pound rammer of approved shape. No cracked or chipped blocks shall remain in the pavement.

After ramming, the spaces between the blocks are to be completely filled with a paving pitch which is the direct result of the distillation of "straight run" coal tar, and of such quality and consistency as shall be approved by the Board of Local Improvements. The pitch must be used at a temperature of not less than 280 degrees Fahrenheit and be spread in such quantity so as to apply two (2) gallons to each square yard of pavement. The spreading must be done in sections if the Engineer so directs.

The contractor or contractors shall provide the Engineer, or his representative, with a duplicate delivery ticket for each and every load or tank of paving pitch delivered on the work. This ticket must be signed by the consignor of the pitch, and be of a form approved by the Board of Local Improvements.

Immediately after the spreading of the paving pitch, and while it is still hot, the blocks shall be covered to a depth of not less than three-quarters (¾") inch with dry roofing gravel. This gravel must be entirely free from sand or loam, and not to exceed one-half (½") inch in size. All

gravel must be clean, washed, dried and heated enough to prevent the chilling of the pitch.

The tarring and top dressing must be completed each day to within five (5′) feet of the face of the blocking.

HEADERS.

At the end of each intersecting street and alley wing there shall be placed a "Header," extending from curb to curb, and so dressed as to conform to the crown of the pavement. The "Header" shall be constructed of three by twelve (3″x12″) inch oak plank, properly supported by six (6″) inch split cedar posts, three (3′) feet in length, firmly set in the ground and spaced not more than five (5′) feet apart.

All "Headers" shall be constructed by the contractor or contractors without extra charge.

CROSSWALKS.

Unless otherwise directed by the Engineer there shall be formed in the pavement four (4) crosswalks at each street intersection, three (3) at each half intersection and one (1) across each and every alley wing and one (1) at the middle of each long block. The crosswalks shall consist of three (3) rows of granite flagstones spaced eighteen (18″) inches apart. The flagstones shall be of the best quality of granite, free from sand pockets, drill holes, seams, or other defects, eighteen (18″) inches wide, five (5″) inches in thickness, and not less than three (3′) feet in length, except where shorter stones may be necessary to make closures, and shall be "bush-hammered" on top, and the sides and ends pitched and dressed to a line so as to make close joints. They shall be firmly bedded in sand and well rammed to a uniform surface.

A gutter nine (9″) inches in the clear width shall be constructed at the ends of the crosswalks by setting granite curbing in the roadway nine (9″) inches from and parallel with the curb line. The granite curbing must be four (4″) inches thick and twenty (20″) inches deep, and the length of the curbing shall be within two (2′) feet of the width of the abutting sidewalk space; provided, however, that the minimum length of said curbing shall be six (6′) feet.

The crosswalks, gutters and their appurtenances shall be formed and constructed where and as directed by the Engineer, and without extra cost over and above the price paid per square yard for the pavement.

MISCELLANEOUS.

DEPOSITS FOR SEWER WORK.

Contractors bidding under these specifications will be required to deposit, and it is hereby understood and agreed that upon the award of the contract for the work under these specifications, the contractor or contractors will deposit—

(1) The sum of three ($3.00) dollars for adjusting—and building (if necessary) of two (2) lineal feet rise of additional brick masonry—of each and every manhole on the line of this improvement.

(2) Ten ($10.00) dollars for the adjusting—and building (if necessary)

of two (2) lineal feet in rise of additional brick masonry—of each and every catch basin on the line of this improvement.

(3) Thirty-five ($35.00) dollars for the building, complete, of each new City of Chicago standard catch basin which may be required.

(4) Seven ($7.00) dollars for the furnishing and setting of each City of Chicago standard cast-iron catch basin or manhole cover which may be required.

(5) Fifty (50) cents per lineal foot of City of Chicago standard nine (9) inch tile pipe; and

(6) Two ($2.00) dollars for each lineal foot in rise of brick masonry required on manholes or catch basins beyond the first two (2′) feet above mentioned.

In consideration of such deposit the contractor or contractors will receive a voucher in the amount of whatever part of such deposit may have been used in the above construction, and in like manner as hereinafter specified on page 6, under "Manner of Payment." Any balance or excess of deposit will be returned to the contractor or contractors.

EIGHT HOURS TO CONSTITUTE A DAY'S LABOR.

In the prosecution of the work under these specifications eight (8) hours shall constitute a day's labor, and any contractor or contractors who shall compel or allow laborers or employes to work more than eight (8) hours in one day shall be liable to have this contract forfeited, as provided by Section 1687 of the Revised Code of the City of Chicago. Provided, however, that in case of emergency the contractor or contractors may, by and with the written consent of the Board of Local Improvements, allow laborers and employes to work extra time.

CHARACTER OF WORK.

All work shall be executed in the best and most workmanlike manner, and no improper materials shall be used but all materials of every kind shall fully answer the specifications, or if not particularly specified, shall be suitable for the place where used and satisfactory to the Board of Local Improvements.

EXTRA WORK.

No claim whatever will be made by the contractor or contractors for extra material or work, or for a greater amount of money than is herein stipulated to be paid, unless some changes in or additions to said work, requiring additional outlay by the contractor or contractors, shall first have been ordered in writing by the said Board of Local Improvements, said writing to be attached to the contract for the making of said improvement and stating that such work is not included in the contract, what the extras are, and that such are necessary for the proper completion of the work, or for the security of the work previously done, and the reason therefor; provided, however, that at the discretion of the Engineer in charge of the work he may order "extras" to the maximum amount of $200.00 in the execution of this contract without the authority of the Board of Local Improvements.

PATENTS.

All fees for any patented invention, article or arrangement or other

appurtenances that may be used upon or in any manner connected with the construction, erection or maintenance of the work, or any part thereof embraced in the contract and these specifications, shall be included in the price stipulated in the contract for said work, and the contractor or contractors must protect and hold harmless the City of Chicago against any and all demands for such fees or claims.

USE OF FIRE HYDRANTS.

Contractors desiring to use water from public hydrants will be required to make application for same to the proper bureau, and conform to the rules and regulations provided in such cases by City ordinances and the rules of the Department.

TIME FOR COMPLETION.

The contractor or contractors shall bid with the express understanding that the work to be performed under these specifications shall be commenced not later than thirty (30) days from the time of awarding the contract for same, and shall be completed on or before......................., and that the said time specified for completion of the work is an essential condition of this contract. Provided, however, that if the contractor or contractors is or are delayed by the City of Chicago in the commencement of the work, or in case the work is suspended by order of the City authorities, then the time of such delay or suspension shall be added to the time for the completion of this contract.

WATER MAINS; HOW PROVIDED FOR.

When the water main shall not have been laid in any street ordered improved and it has been ascertained that there are not enough houses to pay the City of Chicago a revenue of ten (10) cents per lineal foot for every foot of said water main, then the contractor or contractors to whom may be awarded the contract for improving such street, shall advance the money necessary to lay said water main, and the money thus advanced for doing said work shall be returned by the City of Chicago from any moneys not otherwise appropriated when it is shown that a revenue of ten (10) cents per lineal foot of water main is being derived therefrom; provided, that if the money so advanced by the contractor or contractors is not paid back to him or them within two (2) years from the date of the advancement thereof, interest at the rate of five (5) per cent per annum shall be allowed after the expiration of two (2) years until paid.

ALIEN LABOR PROHIBITED.

It is hereby understood and agreed that said contractor or contractors shall not employ, nor permit to be employed by his or their sub-contractors, any person or persons other than native-born or naturalized citizens of the United States.

CONNECTION OF OPENINGS.

It is hereby understood and agreed that the contractor or contractors shall furnish without extra compensation all labor and materials necessary to connect and fit the new pavement with all openings on the line of said pavement in connection with water, sewer, gas, electric conduits, etc., after the same have been brought to the proper grade, and in general everything necessary to render the work fully complete and ready for use.

DAMAGES AND OBSTRUCTIONS.

All loss or damage arising out of the nature of the work to be done, or from any detention or other unforeseen or unusual obstruction, or from difficulties which may be encountered in the prosecution of the work, or from the action of the elements, shall be sustained by the contractor or contractors, who will be required to replace all pavements, etc., without cost to the City of Chicago.

LIABILITY OF CONTRACTORS IN THE MATTER OF OBSTRUCTIONS AND DAMAGE TO WATER, GAS OR DRAIN PIPES.

The Board of Local Improvements reserves the right to take whatever old blocks, planking, granite blocks, or any other old material from the street, and the contractor or contractors will be required to carefully set aside all such material and deliver the same to the City of Chicago, or dispose of it as may be directed by said Board of Local Improvements.

The contractor or contractors shall be required to remove at his or their own expense all obstructions, such as stone, old blocks, debris, trees, etc., that may be in the way of making the improvement.

The contractor or contractors shall remove all surplus materials and debris from the street as the work progresses, so that the public may have the use of the street as soon and as fast as completed.

The contractor or contractors will be required to remove all sidewalks in the way of said improvements in a careful manner, and preserve and replace the same in as good condition as found before removal, at his or their expense.

The contractor or contractors will be held responsible for any damage to the water, gas or drain pipes in addition to the penalty prescribed by ordinance.

During the progress of said improvement the contractor or contractors will be required to keep free and unobstructed any railway along the entire length of the work, keeping all stones, carts, material and all obstructions of whatever sort away from the tracks of such railway so that cars may be run along the same, and said railway to be used in its customary manner without hindrance, and said contractor or contractors will be held liable for all damages resulting from any failure to comply with this stipulation.

If in the prosecution of said work it shall be necessary to dig up, use or occupy any street, alley, highway or public grounds of said City of Chicago, the contractor or contractors shall erect and maintain strong and suitable barriers, and during the night-time lights, such as will effectually prevent any accident or harm to life, limb or property, in consequence of such digging up, use or occupancy of said street, alley, highway or public grounds; and the contractor or contractors shall be liable for all damages occasioned by the digging up, use or occupancy of any street, alley, highway or public grounds, which may result therefrom, or which may result from the carelessness of such contractor or contractors, or his or their agents, employes or workmen, or assigns.

SWORN STATEMENT REQUIRED.

No final estimate or final payment shall be made herein by the City of Chicago or any of its officers or agents until the contractor or contractors

shall deliver to the Board of Local Improvements a statement in writing, setting out fully the amount, kind and quality of the several materials delivered upon, used and incorporated into the work herein required to be done; said statement to be sworn to by said contractor or contractors before a Notary Public or other officer authorized to administer oaths. It is further agreed that the Board of Local Improvements shall have a reasonable time in which to verify the accuracy of such sworn statement before such estimate or final payment is made.

INSPECTION.

Inspectors will be appointed whose duty shall be to point out to the contractor or contractors any neglect or disregard of these specifications; but the right of final acceptance or condemnation of the work will not be waived thereby.

The Board of Local Improvements shall have authority to order the dismissal of any employe on the work who refuses or neglects to obey any of its instructions relating to the carrying out of the provisions and intent of these specifications, or who is incompetent, unfaithful, abusive, threatening or disorderly in his conduct, and such person shall not be again employed on the work.

Upon all questions concerning the execution of the work in accordance with these specifications and the measurements thereof, the decision of the Board of Local Improvements shall be final. Ordinarily one inspector will be employed on the setting of the curbing, one on the foundation and two on the laying of the pavement; but if on account of a disregard of the specifications on the part of the contractor or contractors additional inspectors should be required, such additional inspectors shall be employed by the Board of Local Improvements as it may deem necessary to insure faithful compliance with the contract, and the pay of such additional inspectors shall be charged to said contractor or contractors at the rate of $3.50 per day and deducted from the amount due him or them on settlement.

If at any time during the progress of the work any rejected materials should be found in the street, or any portion of the work being improperly done, such material shall be removed and replaced by proper material and workmanship at the expense of the contractor or contractors.

Notice of any imperfections in the work to any foreman or agent in charge of any portion of the work shall be considered as notice to the contractor or contractors.

CHANGES.

Should the Board of Local Improvements deem it proper or necessary in the execution of the work to make any alterations which shall increase or diminish the quantities or the expense, such alterations or reductions shall not vitiate or annul the contract or agreement hereby entered into, but the said Board of Local Improvements shall determine the value of the work so added or omitted, such value to be added to or to be deducted from the contract price, as the case may be.

PAYMENT IN BONDS.

In case the contract shall provide for payment of the party or parties to whom it shall be awarded in bonds, issued as provided by statute, said

bonds shall be taken for a sum equal to their par value at the time of delivery.

CONTRACTS PAYABLE FROM ASSESSMENTS ONLY.

The work to be done pursuant to this contract shall be done under the direction of the Board of Local Improvements of said City of Chicago, and it is expressly understood that in no case will the said Board of Local Improvements or the said City of Chicago, or any officer thereof, be liable for any portion of the expenses or for any delinquency of persons or property assessed.

MANNER OF PAYMENT.

If the rate of progress shall be satisfactory to the Board of Local Improvements, and when it shall appear that all claims for labor as aforesaid shall have been satisfied, estimates will be issued to said contractor or contractors during the making of said improvement, for eighty-five (85) per cent of the value of the work done and in place, at the time of issuing such estimates, and estimates for the balance or remainder will be issued upon the final completion and acceptance of the work.

The assessment and vouchers drawn, or bonds issued against the same, and interest thereon, and all vouchers or bonds for work issued to the contractor or contractors, and interest thereon, shall be paid only when the assessment levied, or which may hereafter be levied, for said improvement, shall be collected as provided by an Act of the General Assembly of the State of Illinois, entitled, "An Act Concerning Local Improvements," approved June 14th, 1897, in force July 1, 1897, and that said vouchers or bonds, and interest thereon, shall be payable only from such special assessment, and out of no other assessment or fund whatever, and that all vouchers or bonds for a part of any installment, and interest thereon, shall only share pro rata with the vouchers or bonds, and interest thereon, for the remaining part thereof.

In case the City of Chicago should become the purchaser of any special assessment certificates at any sale for the delinquent special assessments, in default of other bidders, such purchase shall not be deemed a collection of such special assessment, and no act of the City of Chicago done or suffered, shall be construed as a collection of any special assessment or part thereof, until the money due thereon shall be actually paid into the treasury of the City of Chicago.

It is understood that the reserve, costs, etc., shall be paid out of the first installment.

It is hereby understood and agreed that the material furnished and used and the workmanship employed in the construction of the said pavement shall be of such character and quality as to insure the same to be free from all defects, and in continuous good order and condition satisfactory to the Board of Local Improvements, ordinary wear excepted, for a period of ten (10) years from and after the completion and acceptance of the same; and as a guarantee of the faithful performance of these specifications, the quality of the material furnished and the proper construction of said improvement, the contractor or contractors hereby agree to keep and maintain the said improvement, without additional charge or cost to the City of Chicago, in

such order and condition as will be satisfactory to the Board of Local Improvements, ordinary wear excepted, for the period of ten (10) years from and after the completion and acceptance of the same, which keeping and maintaining shall include repairs or the entire reconstruction of the same, the necessity for which may be occasioned by or through the use of faulty or inferior material or workmanship, or from any other cause whatsoever; provided, however, the contractor or contractors shall not be required to keep or maintain any part of said improvement, under this guarantee, which after its completion and acceptance shall have been removed for the purpose of laying or repairing any gas, sewer, water or other pipe in accordance with a permit granted by the City of Chicago for such purposes, except as hereinafter provided.

Should the said pavement be cut or removed for the purpose of laying or repairing any gas, sewer, water or other pipe by parties having first obtained a permit from the City of Chicago therefor, the contractor or contractors agree to, within five (5) days after notice so to do from the Board of Local Improvements, relay, repair and repave said pavement in strict accordance with these specifications and with such material and in such manner as will leave the whole pavement in as good and durable condition as it was before the same was cut or removed, the cost thereof to be paid for by the City of Chicago out of its general fund at the following rate: Five ($5.00) dollars for each cut or removal of one (1) square yard or less in area; and for each cut or removal in excess of one (1) square yard in area, five ($5.00) dollars for the first square yard thereof, and three ($3.00) dollars for each square yard and fraction of a square yard additional to the first square yard.

If the contractor or contractors shall fail, neglect or refuse to repair, keep and maintain the said pavement in good order and condition in accordance with these specifications, within five (5) days after notice so to do from the Board of Local Improvements, the said Board of Local Improvements may proceed to do, or cause to have done, the work necessary to comply with the same, and collect the cost and expenses thereof from the contractor or contractors or his or their bondsmen.

DIRECTION AND SUPERINTENDENCE.

The contractor or contractors shall perform all of said work under the direction and superintendence of the Board of Local Improvements of the City of Chicago, and to its entire satisfaction, approval and acceptance. All material to be incorporated in the work, all labor performed, and all appliances, tools and methods used, shall be subject to the inspection and approval or rejection of said Board of Local Improvements, and the said Board of Local Improvements reserves the right to finally decide all questions arising as to the proper performance of said work, and as to whether the rate of progress thereon is such as to correspond with the conditions of these specifications; and if the work shall not be begun at the time herein stipulated, or if the rate at which work shall be performed shall not, in the judgment of the Board of Local Improvements, be such as to insure its progress and completion in the time and manner herein stipulated; or if said work shall be wholly or in part improperly constructed, then to declare the contract for said work forfeited, either as to a portion or the whole of

said work, and to re-let the same, or to order the entire reconstruction of said work if improperly done; and in such case of default, or in any case of default, to adjust the difference of damage or price (if there be any) which, according to the just and reasonable interpretation of these specifications, and the contract as a whole, the contractor or contractors should in the opinion of the said Board of Local Improvements pay to the City of Chicago for any further failure to properly commence and prosecute, or to properly construct said work, in all respects according to the conditions hereinbefore specified, or for any other default; and it is hereby understood and agreed, that for the amount of damage or price determined by said Board of Local Improvements to be paid to said City of Chicago by said contractor or contractors for any such default, or for any money paid out by said City of Chicago on account of said contractor or contractors in consequence of any default, there shall be applied in payment thereof a like amount of any money that may be due and owing to the contractor or contractors on account of said work so far as there may be any such money, and so far as the same shall be sufficient; and if there shall not be sufficient amount retained from said contractor or contractors then and in such case the amount to be paid to the said City of Chicago in consequence of such default shall be a just claim against said contractor or contractors, and be recovered from him or them at law, in the name of the City of Chicago, before any court of competent jurisdiction.

In case the said Board of Local Improvements shall deem it necessary to declare any portion or section of said work forfeited, it is expressly stipulated and understood that such declaration of forfeiture shall not in any manner relieve the contractor or contractors from the covenants and conditions of the contract for said work, but the same shall be and remain valid and binding on said contractor or contractors.

CONTRACTOR'S DEFAULT.

The said work shall be prosecuted with such force as the Board of Local Improvements shall deem adequate to its completion within the time specified, and if at any time the contractor or contractors shall refuse or neglect to prosecute the work with a force sufficient, in the opinion of the said Board of Local Improvements, for its completion within said specified time, or if in any event the contractor or contractors shall fail to proceed with the work in accordance with the requirements and conditions of these specifications, the Board of Local Improvements shall have full right and authority to take the work out of the hands of the contractor or contractors and to employ other workmen to complete the unfinished work, and to deduct the expense thereof from any money that may be due and owing to the contractor or contractors on account of the work, or to re-let the same to other contractors.

In case the contractor or contractors shall abandon or in any way or manner fail to complete said work in the time herein specified, the City of Chicago is hereby authorized and empowered to pay to any laborer or laborers who may have been employed by such contractor or contractors upon the above specified work, out of the funds due said contractor or contractors, uopn the estimates of the Board of Local Improvements, at the time said

Board of Local Improvements shall declare said contract forfeited, any and all sums of money which may be found to be due and owing to such contractor or contractors under said contract, and without giving any notice whatsoever to said contractor or contractors of the intention so to do. And in every such case the City Comptroller is hereby authorized and empowered to ascertain the amount or amounts so due and owing to any such laborer or laborers, from said contractor or contractors in such manner and upon such proof as he may deem sufficient, and without giving any notice of such proceedings to said contractor or contractors; and the amount or amounts so found by him to be due and owing to such laborer or laborers shall be final and conclusive as against said contractor or contractors, and may thereafter be paid over by said City of Chicago to such laborer or laborers. And no estimate will be issued to said contractor or contractors until all claims for labor on this contract shall have been satisfied, said sums of money being payable out of the proceeds of the special assessment levied, and out of the proceeds of any special assessment which shall hereafter be levied for said improvements, when collected.

The contractor or contractors shall make no claim against said City of Chicago in any event, except from the collections of the special assessment made or to be made for said improvement, and to take all risks of the invalidity of any such special assessments, the City of Chicago not to be liable in any event by reason of the invalidity of special assessments, or any of them, or of the proceedings therein, or for failure to collect the same.

ASSIGNMENT PROHIBITED.

No part of the work herein specified shall be assigned or sub-contracted without the written consent of the Board of Local Improvements and in no case shall such consent relieve the contractor or contractors from the obligations herein entered into by the same, or change the terms of this agreement.

In the interpretation of these specifications the decision of the Board of Local Improvements shall be final.

The undersigned hereby certi that he ha read the foregoing specifications, and that h proposal for the work is based on the conditions and requirements embodied therein and should the contract be awarded to h he agree to execute the work in strict accordance herewith.

Name...
Residence...
Name...
Residence...
Name...
Residence...

REMARKS.

On the outside front page of the specifications is a description of the work to be done, together with an estimate of all the quantities of all the materials to be used and the work to be done.

Then follows the Instructions to Bidders, of which a sample is here given from the Granite Block Specifications:

INSTRUCTIONS TO BIDDERS.

It is the intention of these specifications to provide for this improvement in a complete, thorough and workmanlike manner. The contractor or contractors to whom the work is awarded shall furnish all materials, labor and appurtenances necessary to properly complete the work in accordance with these specifications, and anything omitted herein which may be reasonably interpreted as necessary to such completion—the Board of Local Improvements being the judge—is to be merged in the prices bid for the improvement.

No bid will be accepted which does not contain an adequate or reasonable price for each and every item named in the schedule of quantities.

Bidders must satisfy themselves by personal examination of the location of the proposed work, and by such other means as they may prefer, as to the accuracy of the estimate of quantities, and shall not at any time after the submission of an estimate, dispute or complain of such estimate of the engineer, nor assert that there was any misunderstanding in regard to the nature or amount of the work to be done.

Bidders must present satisfactory evidence that they have been regularly engaged in the business of laying granite block pavements, or are reasonably familiar therewith, and that they are fully prepared with the necessary capital, materials and machinery to conduct the work to be contracted for to the satisfaction of the Board of Local Improvements.

Bidders must state in their proposals the name and place of quarrying of the granite they propose to use; and if the granite specified has not previously been tested and accepted by the Board of Local Improvements the bidder shall furnish such sample blocks in ample time so that the said Board of Local Improvements may make the tests it may deem necessary.

All bids must be made subject to the rights of the owners of a majority of the frontage, to contract for the improvement as provided for in Sections 80 and 81 of an Act of the General Assembly of the State of Illinois, entitled "An Act Concerning Local Improvements," approved June 14, 1897; in force July 1, 1897.

No bids will be accepted from any persons or firms who may be in arrears to the City of Chicago upon debt or contract, or who may be in default, as surety or otherwise upon any obligation to said City of Chicago, or behind specified time on any previous work. Companies or firms bidding for the work herein described, must state in the proposals the individual names and places of residence of the persons comprising, or officers of, such company or firm.

The Board of Local Improvements expressly reserves the right to reject any or all bids, or to accept bids separately as to curbing, filling, grading or paving, or to accept any bid in the aggregate.

MACADAM.

For macadam roadways the writer often uses the following specifications:

First specify the rock to be used. It is well to test rock from different local quarries in a rattler, etc., and then name in the speci-

fications all the rock that passes the tests satisfactorily and also allow any other rock that will pass the tests.

Then specify the preparation of the roadway and require the rolling to be done with a roller of not less than five tons weight and to be rolled and sprinkled alternately until a wagon with two inch tires carrying not less than one ton can be drawn over without cutting or very appreciable settlement.

Upon the earth foundation shall be spread the macadam in three layers. The lower layer when compacted shall constitute one-half the thickness of the finished roadway. No stone in it shall exceed in any dimension one-half the thickness of the said layer. Not to exceed twenty per cent of the stone shall be small enough to go through a half-inch mesh and be retained on a one-eighth inch mesh. The remainder of the stone shall be fairly uniform in varying sizes between the extremes permitted.

After the lower layer is spread with rakes and forks it shall be rolled and sprinkled alternately until it ceases to move under the roller, fine stone dust or sand, or both stone dust and sand being added from time to time to fill the interstices and assist in holding the material firm. When rolled until a wagon with two inch tires and loaded with not less than one ton, can be taken over it without causing the stone to be displaced, or making an appreciable rut, the spreading of the second layer may be commenced.

The second layer when compacted shall constitute one-third the thickness of the finished roadway. No stone in it shall exceed in any dimension one-half the thickness of the said layer. Not to exceed twenty per cent shall be small enough to pass a half-inch mesh and be retained on a one-eighth inch mesh. The remainder of the stone shall be fairly uniform in varying sizes between the extremes permitted.

The second layer shall be rolled, sprinkled, spread and bound in the same manner as required for the first layer.

The third layer shall complete the total thickness of the pavement. No piece of stone in it shall exceed in any dimension one-half the thickness of the said layer. Not to exceed twenty per cent shall be as fine as stone dust or such as will pass a one-eighth inch mesh. The remainder to range uniformly between the extreme sizes permitted.

This third, and final, layer shall be spread, sprinkled, rolled and bound as specified for the two lower layers.

The surface of the roadway shall present a uniform and smooth appearance and conform to the lines and levels of the engineer in charge. The engineer before accepting the work can cover the roadway with water and the contractor shall pick and refill all depressions that contain more than one-half inch in depth of water and if a depression containing in the center one-half inch of water, be less than four feet across then such hole must be picked and refilled, under the direction of the engineer.

For heavy traffic on a business street the thickness can be twelve inches. No particular object is gained in making it more. On residence streets with extremely light travel and a good soil

six inches is ample if drainage is taken care of. Streets with medium traffic can have eight or nine inch macadam.

SPECIFICATIONS FOR GRAVEL ROADS.

(For the preparation of the earth foundations ideas can be found in foregoing specifications. The same may be said of the cleaning up specifications.)

Upon the earth foundation thus prepared spread a layer of clean gravel four inches thick. None of the gravel shall exceed two inches in any dimension and it shall be graded from that size down to sand in such proportions that a minimum of voids shall be left. It is to be spread in an even layer and sprinkled and rolled until it ceases to move under the roller. If it does not compact readily a thin coating of clay or loam shall be placed over it and washed into the interstices.

On top of this lower layer shall be placed a layer of clean, sharp gravel, free from pieces round like marbles, and from which all pieces exceeding three-quarters of an inch in all dimensions shall be excluded. This layer shall be sprinkled and rolled like the lower layer but instead of clay or loam being used as a binder if it does not compact, it should be bound with fine sand or rock dust.

BITULITHIC PAVEMENT.

The following specifications were used in Cincinnati in 1904-5:

EARTH FOUNDATION.

The earth foundation or sub-grade will be brought to an even surface parallel with the grade proposed for the pavement, by making the necessary excavation or embankment. Soft or spongy earth, or other material not firm, will be removed, and the space filled with stone or with extra concrete, as specified for pavement base. The sub-grade surface will be compacted by rolling and ramming. Any portion not accessible to the roller shall be thoroughly compacted by ramming. When this shall have been done, the surface shall be true, smooth and eight inches below the finished surface for the pavement. Excavation shall be paid for at the price bid per cubic yard, and crushed stone or concrete per cubic yard at the price bid for same. All excavated material shall belong to the contractor.

PAVEMENT BASE.

Upon the earth foundation prepared as specified shall be laid a layer of crushed granite boulders or hard limestone that after its ultimate compression by rolling and ramming shall have a depth of six inches. The surface of the layer of stone will be true, exactly parallel with and two inches below the surface proposed for the finished pavement. The crushed stone shall

be sound and clean, the fragments being uniformly graded in sizes from a material that will pass a three-inch screen to material that will stand on a one-inch screen, and the various sizes shall be laid in strata, each stratum passing through a screen having perforations with a diameter not to exceed one inch larger than the diameter in the screen through which the material refused to pass.

The layer of crushed stone prepared as specified will be coated with Warren's No. 1 Puritan brand semi-liquid composition, or material of the same chemical and physical properties, said bitumen to be sufficiently flexible to unite freely with the cold stone. On top of this composition shall be spread a heavy coating of Warren's No. 24 Puritan brand hard bituminous cement, or material of the same chemical and physical properties, thoroughly binding the pavement base and making it readily unite with the bituminous concrete wearing surface. One gallon of bituminous cement will be used to each square yard of surface. On this prepared pavement base sha'l be laid the wearing surface, which shall be composed of carefully selected hard crushed stone, mixed with bitumen and laid as herein specified.

WEARING SURFACE.

After heating the stone in a rotary mechanical drier to a temperature not to exceed 250° F., it shall be elevated and passed through a rotary screen having six or more sections with varying sized openings, the maximum of which shall be 1¾ inches and the minimum 0.1 inches diameter. The several sizes of stone thus separated by the screen sections shall pass into a bin containing six sections or compartments. From this bin the stone shall be drawn into a weigh box resting on a scale having seven beams. The stone from each bin shall be accurately weighed in the proportion which has been previously determined by laboratory tests to give the best results—that is, the most dense mixture of mineral aggregate, and one having inherent stability. From the weigh-box each batch of mineral aggregate, composed of different sizes accurately weighed as above, shall pass into a "twin pug," or other approved form of mixer. In the mixture shall be added a sufficient quantity of Warren's Puritan brand bituminous waterproof cement, varied from No. 19 to No. 24, or material having the same chemical and physical characteristics to suit the stone used, in sufficient quantity to thoroughly coat all the particles of stone and to fill all voids in the mixture.

The bituminous cement shall, before mixing with the stone, be heated to between 200° and 250° F., the amount used in each batch shall be accurately weighed and used in such proportions as has been previously determined by laboratory examination to give the best results and to fill the voids in the mineral aggregates. The mixing shall be continued until the combination is a uniform concrete. In this condition it shall be hauled to the street and there spread in the prepared foundation to such a depth that, after thorough compression with a steam road roller, it shall have a thickness of two inches. The proportioning of the varying sizes of stone and bituminous cement shall be such that the compressed mixture shall, as closely as practicable, have the solidity and density of solid stone.

SURFACE FINISH.

After the rolling of the wearing surface there shall be spread over it a

thin coating of Warren's quick-drying bituminous flush coat composition, or material of the same chemical and physical characteristics, the purpose of this coating being to thoroughly fill any unevenness or honeycomb which may appear in the surface of the mixture. There shall then be rolled into the surface a thin layer of stone chips for the purpose of presenting a gritty surface which will not be slippery, the size of the stone chips to be subject to the special direction of the Engineer. The stone chips will be of the same quality as stone specified for the wearing surface.

The roller used for compacting the earth foundation or sub-grade, for compressing the pavement base and wearing surface, also for rolling the stone chips, shall be operated by steam power and give a weight pressure of not less than 650 pounds per lineal inch of roller.

Each layer of the work shall be kept free from dirt so that it will unite with the succeeding layer.

PORTLAND CEMENT CONCRETE.

When, on rolling the sub-foundation, it is found impossible to make the street sufficiently solid to hold up the roller, the contractor shall be required to furnish a Portland cement concrete foundation, to be laid under the following specifications: The concrete shall consist of mortar and crushed stone, gravel or slag, which will vary in size from ¼ inch to 3 inches, mixed in such proportions as will provide a solid concrete. The mortar shall consist of one part of Portland cement to three parts of clean, sharp, coarse sand, and shall be used with crushed stone in predetermined proportions to give a firm, solid concrete. As soon as the concrete is well tamped, and before it becomes set, there shall be scattered over the surface of the concrete a sufficient quantity of clean broken stone of such size as will pass a 1½-inch or 2-inch opening on a rotary screen. Sufficient of the stone to be used to about half cover the concrete. This stone shall then be tamped so as to become well bedded into the surface of the concrete, leaving a rough surface to the foundation of the pavement. The object of this binding course of crushed stone is to afford a rough surface to the concrete to enable the bitulithic wearing surface to more firmly adhere to the same.

If the fine crushed stone does not provide the best proportions of fine-grained particles, they must be supplied by the use of not to exceed 15 per cent of hydraulic cement, pulverized stone or very fine sand.

MATERIALS.

The bituminous cement shall be prepared by selecting bitumen which has been distilled from coal and passed in a gaseous state through water and purified by water, removing therefrom all matter soluble in water, and only that bituminous material shall be used which condenses from the gaseous state in water. The material selected shall be mixed in fixed proportions so as to give and produce a uniform condition as to the quantity of free carbon. The bituminous cement shall not be adulterated with any class of asphalt, coke-oven coal tar, water-gas coal tar, or any of the products of petroleum, and shall be especially refined and distilled at temperatures never rising above 450° F., using such forms of mechanical steam and air agitation as will accomplish uniformity of results, and remove, as far as possible, napthalene and other matters most susceptible to atmospheric influences.

The bituminous cement shall be of such quality that when three ounces is placed in a glass dish three inches in diameter in the sun for two years it shall be decreased less in its penetration (taking the penetration of 1/16 inch below its surface) than the best quality of Trinidad Lake asphalt paving cement for the same original penetration at 79° F. The bituminous cement shall be of such character that when nine parts of the cement are mixed with 92 parts of sand which will pass a 20-mesh sieve and stand on a 30-mesh sieve, and placed in water, it shall show no discoloration at the end of three months when placed subject to the chemical influence of the sun during parts of the day, and shall be firmer, as shown by testing on an ordinary cement tester at the end of six months, than a Trinidad asphalt cement submitted to the same condition will show at the end of two weeks.

The mineral ingredients shall be so arranged as to sizes that they will have inherent stability independent of the bitumen so as to stand a weight of at least three tons on a four-wheeled vehicle with three-inch tires without the bitumen. The pure bitumen used in the wearing surface shall be of such softness that it will not be harder in penetration at 70° F. than a Trinidad asphalt paving cement, composed of 100 parts refined Trinidad Lake asphalt and thirty parts petroleum residuum, at 18° Beaume.

GUARANTEE.

The price bid per square yard to include repairs necessary to maintain the pavement in good condition, satisfactory to the Board of Public Service, for a period of five years from the date of acceptance by the city.

GENERAL.

Under these specifications it is intended to get a wearing surface which is two inches in depth over all, and it shall be the option of the bidder to use a bituminous binder course to level up the foundation or to level it up with a part of the wearing surface mixture. The binder course, if used, shall be fine particles of stone or gravel not to exceed one inch in diameter, thoroughly coated with Warren's Puritan brand bituminous waterproof cement No. 19 to No. 24, or material with the same chemical and physical characteristics.

The attention of bidders on the bitulithic pavement is called to the agreement on file with the Council of the City of Cincinnati, under date of October 3, 1904, and bidders are hereby notified that the sum of 25 cents per square yard will be retained from the contract price, and that the city will pay the same direct to Warren Brothers Company for the patent rights and service therein granted.

PATENTED BITULITHIC PAVEMENTS.

The introduction of bitulithic pavements has been hindered in many cities owing to the fact that patented materials are generally forbidden because tending to create a monopoly and thus preventing free competition.

The securing of perfectly free competition does not always insure the securing of the best materials and such laws often prevent the

people taking advantage of progress in methods of doing public work. In a number of cities the use of patented pavements has been allowed after trial in courts.

CONCRETE.

The first good pavements of concrete were laid in Richmond, Ind. Mr. H. L. Weber, the city engineer, in a paper before the Ohio Engineering Society gave the following:

SPECIFICATIONS.

SECTION 1.—The Contractor shall furnish all the labor, tools and materials necessary for the completion of the cement work and accessories as herein specified; also furnish all labor and materials required for protecting and repairing adjacent structures, maintaining public travel on the street or intercepted roads, walks and streets; all labor and materials required for any of the operations, principal or collateral, mentioned or implied herein.

All materials and labor shall be subject to the inspection and acceptance of the Engineer and Superintendent in charge.

SUB-GRADE.

SEC. 2.—Excavate to the full width and depth below the top of the grade stakes, as shown by plans. The material excavated shall be delivered by the Contractor to such lots or tracts of land abutting upon the improvement that may require filling. After such lots are filled, the remaining material shall be delivered to such points as the Board of Public Improvements or Engineer may designate, provided the haul does not exceed one thousand yards, otherwise said material shall belong to the Contractor, to be disposed of.

SUB-DRAINS.

SEC. 3.—Sub-Drains shall be laid of three or four (3" or 4") inch common drain tile, eight (8") inches below the sub-grade as shown by the plans. The tile shall be laid to a true grade and line, with close fitting joints, with clean gravel packed around and over them to the top of the trench. The tile shall be connected to such outlets as the Engineer may determine. All junctions to be made with "Y" and "T" branches, and all deflections with curves of vitrified sewer pipe.

TREES, ROOTS, ETC.

SEC. 4.—Trees shall not be injured, but roots of trees, which in any way interfere with the construction of the walk and its maintenance in proper manner, shall be cut away as the Engineer may direct. The pavement shall be properly fitted around all fixtures in the walk.

RELAYING, ETC.

SEC. 5.—Where the material in any walks that now exist on the street shall be acceptable to the Board of Public Improvements, they shall be relaid to the grade and line established; the price therefor shall be determined by adding 10 per cent to the actual cost of the work as determined by the Engineer.

FOUNDATION "A."

SEC. 6.—Upon the sub-grade shall be placed clean, coarse gravel, eight (8") inches in thickness after being thoroughly wet and rammed, and to a uniform depth of four to six (4" to 6") inches below the finished grade.

FOUNDATION "B."

SEC. 7.—Upon the sub-grade, prepared as shown by the cross section and as above specified, there will be placed a six (6") inch layer of rubble, or field cobble stone, the refuse of quarries, old bowlders taken from the old bowlder curbing (if too large they shall be broken if used), or coarse gravel. Upon this layer shall be placed sufficient gravel to fill the interstices, and form a foundation with a total depth of eight (8") inches, after being leveled off and settled by flooding and ramming. Upon this bed will be placed a layer of good, clean gravel, two (2") inches in depth, to be properly spread, packed, and smoothed, to receive the concrete curbing.

CONCRETE.

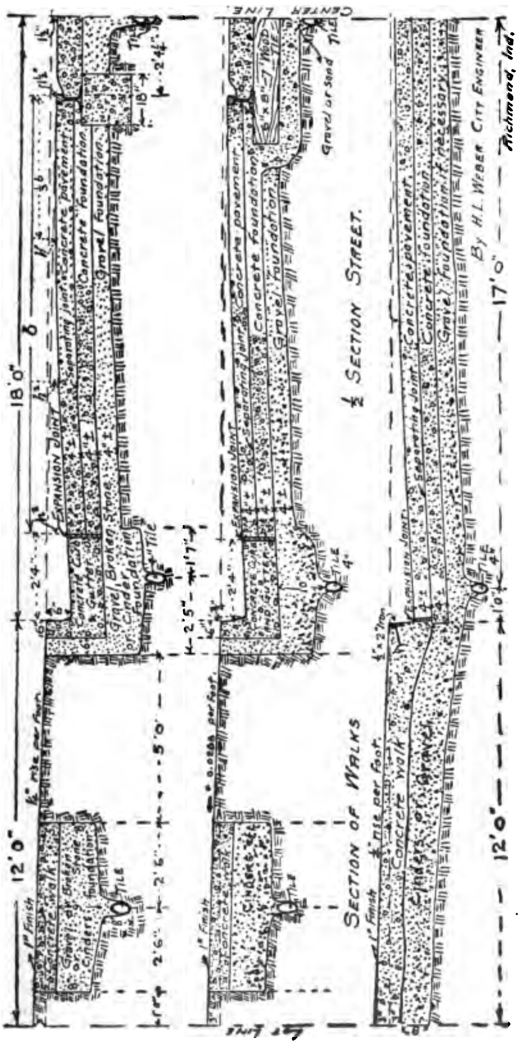
SEC. 8.—Upon the foundation place the concrete, four to six (4" to 6") inches thick after being thoroughly rammed; it shall be uniformly one (1") inch below the finished grade. The facing shall be placed in the templets forming the curb, backed up with concrete thoroughly rammed to place.

The concrete shall be composed of one part cement, two parts sand, and four (4) parts gravel; the gravel can contain the sand, and two (2) parts clean screened, crushed lime stone. The proportioning of the cement, gravel and stone shall be done by placing a templet of the proper size upon a platform and placing therein the sand, gravel or stone by actual measurement in the proper quantities, leveling off the form with a straight edge; over the top evenly spread the cement in the proper proportions; remove the templet, turn the mass at least twice thoroughly, or until it is thoroughly mixed, add clean water from sprinkling can and thoroughly mix to make a concrete of such consistency that when deposited and rammed to place shall envelop every particle of sand with the cement, and every particle of gravel or stone with mortar. This result must be obtained to the entire satisfaction of the Engineer.

The concrete shall be laid in blocks of the following dimensions: Six by seven (6'x7') feet for seven (7) foot walk; six by six (6'x6') feet for six (6) foot walk; and six by five (6'x5') feet for five (5') foot walk, with expansion joint separated by two pieces of three-ply tarred paper, at each 33 feet of line, and intermediate joints with dry sand, as the Engineer may direct.

WEARING SURFACE.

SEC. 9.—Before the concrete has set, deposit the wearing surface, which shall be one (1") inch in thickness, composed of one part cement and two parts clean, coarse, washed sand, if the nature of the material require it; or one part cement, one part sand, and one part clean, crushed stone screenings. First mixed thoroughly in a dry state, then add sufficient clean water, and thoroughly mix into a medium soft mortar. Deposit this upon the concrete and trowel down to insure a perfect contact, then level with a straight edge from the grade strips. When sufficiently hard, float and trowel to a smooth continuous surface. Avoid dusting the surface with dry cement.



CONCRETE ROADWAYS.

In order to show details clearly the vertical scale is exaggerated. Horizontal scale $\frac{2}{3}$ Vertical

CROWN FOR STREET. = H = total crown. Let $B = \frac{1}{2}$ width of street

$h' = (\frac{1}{3})^2 h = \frac{1}{9} h$ $h'' = (\frac{2}{3})^2 h = \frac{4}{9} h$ $h''' = (\frac{3}{3})^2 h = h$ = crown.

The surface, except a marginal draft two inches wide around each plate and five inches along curb line, shall be pitted with a brass roller acceptable to the Engineer.

The wearing surface shall be cut in blocks the same size as the concrete base. As soon as the work has properly set, all templets to be removed and edges plastered to the full depth of templets, if required by the Engineer.

All walks shall have a rise of one-fourth inch per foot from the curb to the lot line. Strips properly staked shall be set on both sides of the walk to keep straight, being careful that the grade and fall are correct. Any walk not properly laid, must be taken up and relaid by the Contractor.

CEMENT CURB, GUTTER AND CROSSWALKS.

SEC. 10.—The cement curb, gutter and crosswalks shall be constructed in place, under the direction of the Engineer, upon a bed of gravel, eight to ten (8" to 10") inches in depth, after being flooded with water and compactly rammed to an even surface. Upon the sub-grade will be laid the foundation A or B as shown by plan. The curb and gutter or crosswalks will be composed of concrete, formed by intimately mixing, dry, one (1) part Portland cement, two (2) parts coarse, clean sand, washed if necessary, three (3) parts of clean, medium sized gravel, and two (2) parts of clean, screened lime stone, crushed to pass through a screen of one and one-half mesh, to which add sufficient clean water to form a concrete, that, when placed in the templets and thoroughly rammed, free mortar will appear on the surface. The ramming of the concrete in the forms shall be done with the proper tamping bars and other tools to insure a compact homogeneous mass, with full square corners. The stone shall be sprinkled before it is added to the mortar. The proportions given being intended to form a concrete in which every particle of sand shall be enveloped by cement, and every particle of gravel and stone enveloped by mortar, this result must be obtained to the satisfaction of the Engineer. All exposed surfaces shall be covered with a finish coat one (1) inch in thickness, composed of one part cement, one part of fine, clean stone screenings, and one (1) part of clean, coarse sand.

The facing shall be placed in the templets forming the curb backed up with concrete and thoroughly rammed to place. The top facing of curb and gutter shall be thoroughly troweled to insure perfect contact. When sufficiently hard, float and trowel to a smooth true surface. The curb to be constructed with the top edge to the established grade of the street; the upper and lower face corner to be rounded to a radius of one inch. The curb shall be six inches thick at the top, and the gutter eight (8") inches thick, and twenty-eight (28") inches wide, and constructed in seven-foot sections, alternately. When the intervening sections are constructed there shall be a strip of tarred paper placed in the joints, as the Engineer may direct.

The proportioning of the cement, sand, stone and gravel shall be done by placing a templet of proper size upon a platform, and placing therein the cement, sand, stone and gravel in the proper quantities by actual measurement, leveling off the templets with a straight edge. Wrought iron protections will be built in all corners and places designated.

ROADWAY PAVEMENT.

Sec. 11.—The sub-grade will be thoroughly rolled, leveled and re-rolled until it is true to grade and cross-section of the finished roadway, and from eight to twelve (8" to 12") inches below the surface of the street, as the case may be.

If found necessary for sub-drainage, upon the sub-grade, place three to four (3" to 4") inches of gravel, thoroughly wet and consolidated by rolling or ramming, or both. Upon this gravel foundation will be placed a layer of concrete from four to five (4" to 5") inches in thickness and finished to a true crown and grade, parallel to the finished street surface and three to four (3" to 4") inches below the same. This will constitute the foundation for the cement roadway.

When sufficiently strong to sustain the roadway paving, the surface of the concrete foundation will be covered with a coating of fine sand, raked off with a flat board rake, by hand, so as to remove all sand except that which may remain in low places and voids in the concrete foundation.

Upon this will be placed a layer of thin tar paper (or other suitable paper) or material to act as a separating joint.

Upon this will be laid the concrete pavement two to three (2" to 3") inches thick, in sections the full width of the street and ...... feet in length, with expansion joints next the gutters and ends.

This roadway concrete will be composed of one part cement, two parts sand, three parts gravel, and two parts crushed stone, mixed with water to form a rather wet mixture.

Upon this will be placed the wearing surface, one inch thick, composed of one part cement, one part clean, sharp sand, and one part clean stone or granite screenings, mixed with water to form a rather wet facing mixture.

The wearing surface will be deposited in two layers, one-half inch thick, the first to be thoroughly rammed to insure perfect contact; the second applied immediately after, and thoroughly troweled and worked over, and made to conform to the finished surface of the street by the use of the proper forms.

When sufficiently hard, the surface to be floated and steel troweled, and, lastly, raised with a cork float, and when finished must be true to grade and cross-section.

All concrete must be machine made, or thoroughly mixed by hand, as the Engineer may direct.

CEMENT.

Sec. 12.—(Note: The writer advises in this section the Standard Cement Specifications of the American Society for Testing Materials, instead of those used in Richmond, Ind.)

SAND.

Sec. 13.—The sand shall be clean, coarse river or bank sand, acceptable to the Engineer.

WATER.

Sec. 14.—None but clean, clear water shall be used, which must be furnished by the Contractor.

As soon as a section is finished it shall be protected by placing muslin or canvas thereon, and in dry weather it must be kept moist for five days by thorough sprinkling.

STREET CROSSINGS.

SEC. 15.—Where drive ways, alley crossings, or street crossings occur in the line of walk, the walks will be made of special construction as shown by plans, or as directed by the Engineer. Letters shall be placed as directed by the Engineer.

WORK SUSPENDED.

SEC. 16.—Any work not finished in the time specified, shall be discontinued for the season, upon notice from the Board of Public Improvements, and not again commenced until said Board shall order the Contractor to begin work. No work shall be laid in freezing weather.

STEPS.

SEC. 17.—At points where it will be necessary to construct platforms, steps, or other appurtenances, along any building in order to harmonize said building to the established grade, the outside line of said appurtenances shall be .... feet from the curb line, and parallel therewith, and constructed as shown by plans and detail drawing.

In Bellefontaine, Ohio, a pavement that had been down for thirteen years was inspected by a committee from Richmond, Ind. The committee reported that although the pavement was extremely durable it was unpopular because so slippery in all seasons.

The committee reported that in their opinion it was because the surface was finished with a steel trowel, whereas in Richmond after steel trowelling the surface was trowelled with a cork trowel. The corrugations and ridges left in the Bellefontaine pavement was another objection. The Bellefontaine specifications were as follows:

CEMENT PAVEMENT.

SECTION 1.—The lower strata of the cement pavement or grout must be four inches thick, composed of one part of best Portland cement equal to the Buckeye Portland cement to four parts of clean, sharp gravel and sand, in which the proportion of the sand is about one-half that of the gravel. This must be thoroughly mixed by a screw mixer and so much water thoroughly incorporated during the mixing process as will show on the surface of the concrete after it has been well rammed to place, which must be done as expeditiously as possible after the mixing, and the concrete must be made solid and complete at once after being dumped in place.

SEC. 2.—After the lower strata has been placed and before it has thoroughly set, then the top, two inches thick, composed of equal parts of the Portland cement and coarse, sharp sand and gravel, sifted to the size of a pea, then wet mixed and rammed the same as the grout, a very thin layer of pure cement must be well rubbed into the concrete surface, first to insure adhesion, then the entire coat must be added before the concrete is set.

Sec. 3.—The entire concrete and top must be separated carefully and regularly into blocks five feet square and the edges neatly finished, and the surface grooved in continuous lines from side to side every four inches, the grooves being V shaped, three-sixteenth inches deep and one inch wide, to be troweled smooth, the entire pavement being carefully built to the grade givn by the engineer, must present a true crown, as represented on the cross section prepared for the same.

Sec. 4.—A row of blocks on one side to have joints sloping in such manner that they can be raised without disturbing the other blocks.

Sec. 5.—Curbs, one part cement to three parts sand, six inches wide of same material, to be raised on each side to a level with the sidewalks as per engineer's plan.

Sec. 6.—The whole work, when completed to be covered two inches deep with wet sand and kept in that condition for one week after completion of the contract.

Sec. 7.—The above specified work, when completed is to be first-class in every particular and is to be guaranteed by the contractor to last a relative time longer than any brick paving, as the contract price exceeds the contract price of the brick or any like material of which there may be a competitive bid.

Sec. 8.—All work to be in strict conformity to the plans, specifications and cross-section of the improvement and to be carried out under the general requirement as hereinafter specified.

HASSAM PAVEMENT SPECIFICATIONS.

Note—Hassam pavement is laid on a cement-concrete pavement or it is sometimes used as a foundation for other paving materials.

The following complete specifications call for its use as a foundation for stone paving blocks.

To provide for its use as a cement-concrete pavement, use the same specifications up to and including Section 15. Omit all the remainder and substitute the following:

PAVING.

Upon the sub-grade, after being thoroughly rolled or compressed to a true and even sufarce at least (6") inches below the finished grade, shall be spread a layer of stone, varying in size from 2½" to 1½" to conform with the grades and contour of the street after rolling. After this stone has been thoroughly compacted by rolling or compression and firmly imbedded and the voids reduced to a minimum, it shall be grouted with a grout consisting of one part Portland cement to two parts sand. This grout shall be poured upon the stone until all the voids are filled and the grout flushes to the sufrace. The rolling or compression to continue during the process of grouting. Upon this surface shall be placed a very thin layer of pea stone, which shall be spread and rolled or compressed even and smooth over the entire surface, rolling to continue until grout flushes to surface.

EXPANSION JOINTS.

Suitable expansion joints shall be provided at the curb and across the street, as the contractor may direct.

No concrete shall be laid when the temperature at any time, day or night, falls below 35° F.

STREET CLOSED.

All paving shall be kept without travel for a period of at least six (6) days after the completion, if necessary in the judgment of the contractor, before being opened to the public for use.

MARKING OF PAVING.

Every street laid shall be marked with a suitable mark, with the inscription, "Patented May 1, 1906."

SPECIFICATIONS FOR LAYING HASSAM PAVEMENT WITH GRANITE TOP.

GENERAL PROVISIONS.

1. All material and debris shall be removed from the street as the new work progresses so that the public may have use of the street as soon as possible.

2. The contractor shall, at any time, furnish such samples of material as the Engineer or Street Commissioner may require for making tests.

Any material condemned by them shall be at once removed by the contractor in the vicinity of the work.

3. Any work condemned by the Engineer or Street Commissioner shall be immediately rebuilt or the defect otherwise remedied as the Engineer or Street Commissioner may direct, and if, in any case, the contractor shall refuse or neglect such defect as ordered, then the city may cause such condemned portion to be removed, rebuilt or repaired at the expense of the contractor.

4. Barriers and lights from sunset until sunrise shall be maintained at all streets and alley intersections and all other points open to public traffic. Such protection shall be to the full satisfaction of the Engineer or Superintendent of Streets.

5. Work shall be begun at such points and at such times as the Engineer may direct.

6. Upon any stoppage of the work all material shall be neatly piled up so as not to impede traffic on said work and so as not to prevent the use of fire plugs or drainage in gutters, and all rubbish and surplus material shall be removed immediately from the street, avenue or alley by the contractor.

7. When the word "Engineer" is used in these specifications it shall be held to mean the Engineer placed by the proper authorities of the city, in charge of the construction of the work herein contracted for, or an Assistant Engineer actually in charge of the work in the absence of the Enigneer.

GRADING.

8. The road bed shall be brought to a sub-grade which will be below the established grade of the street, a depth equal to the thickness of the proposed pavement, and shall be graded to the exact form of the cross-sections shown on plan.

9. In places where fill is required it will be made with any suitable material excavated from the improvement.

All filling must be made in uniform layers not over six inches (6") in depth, and each layer shall be thoroughly rolled or tamped as may be required to insure a solid bed.

10. The road bed then shall be brought to the exact sub-grade by thoroughly rolling or tamping as may be required to secure a solid sub-grade.

Soft and spongy places not affording a firm foundation shall be dug out and refilled with good, sound earth, cinders, gravel, slag or stone as the city may direct.

Such excavation and filling to be paid for at actual, reasonable cost of labor and material plus fifteen per cent.

11. All excavated material not used on this work shall be the property of the city and shall be deposited in such place as the Engineer or Superintendent of Streets shall direct. The maximum length of haul not to exceed 2,000 feet. All over-haul shall be paid for at the rate of two cents ($.02) per cubic yard for each 500 feet or fraction thereof of over-haul.

REQUIREMENTS OF MATERIALS.

12. All cement used on this work must fulfill the requirements of the specifications contained in No. 28 of the Professional Papers of the Corps of Engineers of the United States Army.

13. Sand. The sand shall be clean and sharp and free from clay, loam or organic matter.

14. Stone. The stone may be of any proper or suitable grain or quality.

15. Water. All water necessary for the construction of the pavement shall be furnished free of cost to the contractor by the city of ....

HASSAM CONCRETE FOUNDATION.

16. Upon the sub-grade prepared in accordance with the specifications for grading, broken stone or gravel shall be spread so that after rolling or compressing, it shall have a uniform thickness of 4 ins.

17. After this stone has been thoroughly compacted and firmly imbedded and the voids reduced to a minimum, it shall be grouted with a grout of Portland cement and sand, consisting of 1 part Portland cement and 4 parts sand; said grout to be mixed in a Hassam grout mixer to insure the accurate blending of the ingredients.

This grout shall be poured upon the foundation until all the voids are filled and the grout flushes to the surface. The stone to be rolled or compressed during the process of grouting.

18. No concrete shall be laid when the temperature at any time, day or night, falls below 35° F.

PAVING BLOCKS.

19. The paving blocks shall be of the following dimensions:

4 to 4½ ins. high, 3½ to 4½ ins. wide and 6 to 12 ins. long, to be made of good, first quality granite.

20. On the foundation of concrete laid as above specified shall be laid a layer of coarse, sharp sand 1½ ins. in thickness.

21. Upon this base of sand the granite blocks shall be laid on edge, end to end, across the street at right angles to the curb.

The blocks must be closely and evenly laid in true lines and care must be taken to break the joints with a lap of at least 2 ins.

22. These blocks shall be stiffened by sprinkling pea stone on the surface and sweeping it with a wire broom.

The surface of the pavement shall then be made even and true by rolling

with a roller weighing not more than six tons. At points which cannot be reached with a roller, the surface of the pavement shall be tamped with tampers weighing not less than 75 lbs. so as to bring all blocks to a uniform and smooth surface.

23. None but practical and competent pavers shall be employed in laying the blocks.

24. After the pavement has been rolled, the surface shall be swept clean and the joints shall be filled with a grout and by regrouting until they remain full to the surface. Said grout to be made of 1 part Portland cement equal in quality to the best American Portland cement and 1 part of clean, sharp sand with enough water added to make a grout of the proper consistency, said grout to be mixed in Hassam grout mixer to insure the accurate blending of the ingredients.

25. The grout shall be poured on the paving and shall be brushed into the joints.

26. The blocks shall be wet by sprinkling immediately before applying the grout.

27. The grout shall be poured until all joints are full and flushed to the surface, after which it shall be broomed with a street broom to an even and smooth surface.

28. All paving shall be kept without traffic for a period of at least six days after completion, if necessary in the judgment of the contractor, before being opened to the public for use.

PETROLITHIC PAVEMENT SPECIFICATIONS NO. 61

FOR GRADING STREETS (CLASS H) IN THE CITY OF LOS ANGELES.

—1—

PLANS, ETC.

The work herein provided for is to be done in accordance with the plans, profiles and cross-sections on file in the office of the City Engineer of the City of Los Angeles and all work shall, during its progress and on its completion, conform to the lines and levels which may, from time to time, be given by said City Engineer.

—2—

GRADING.

Grading shall include all filling, the removal of all earth, stone, or all other material of whatever nature it may be, that may be encountered in preparing the street, and shall also include all trimming and shaping required to bring the surface of the street to grade and cross-section. When mud or other soft material is encountered it shall be taken out and the space filled with good earth or gravel. The contractor, however, will not be required, in such cases, to excavate the mud or other soft material to a greater depth than two feet below grade. All filling shall be done with good, sound earth. The embankments shall be carried up, of full width, in horizontal layers not to exceed one foot each in thickness, and the teams shall be made to travel as evenly as possible over the whole surface of each layer, both going and coming. The formation of well-defined ruts is especially prohibited. No material of a spongy nature shall be used for filling. The space over which fills are to be made shall first be cleared of all brush or timber.

The required grade and cross-section, after being thoroughly compacted, of the surface of the natural material of the street in that portion of the street

which is to be oiled, shall be two inches below the finished surface of the street and parallel thereto.

The roadbed surface shall be rolled with a roller weighing not less than 250 pounds to the inch width of tire, until it is unyielding. Depressions made by the rolling shall be leveled up with good earth and again rolled. Such portions of the street as can not be reached by the roller, and all places excavated below grade and refilled, and all pipe trenches and other places that can not be properly compacted by the roller, shall be tamped solid, and in case of wet weather or soft or muddy ground, making use of the roller unsafe or impracticable, the rolling shall not be undertaken until the ground has become sufficiently dry.

The roadbed shall then be tested for grade and cross-section, and no further work shall be done upon it until a certificate shall have been issued stating that it is acceptable in these respects. It shall then be plowed to a depth of six to nine inches and thoroughly pulverized by cultivating and harrowing.

All stone larger than that which will pass through a ring two inches in diameter shall be removed, and the surface shall then be rolled with a roller of a form described hereinafter, until it is solidly compacted up to within four inches of the top [forming a substantial sub-base].

—3—

OILING.

Oil shall then be applied as follows:

The area to be oiled shall extend from curb to curb where there are no gutters, and where there are gutters, then from gutter to gutter, including all intersections of streets and alleys, and to the property lines on both sides of said intersections.

The roadway shall be coated evenly with the oil at the rate of three-fourths of one gallon to the square yard of surface covered. It shall then be thoroughly cultivated to a depth of four inches until the oil is well mixed with the soil. A second application of oil, at the rate of three-fourths of one gallon to the square yard of surface covered shall then be made, and the area shall be again cultivated to a depth of four inches until the oil and the soil are well mixed. The roadway shall then be plowed four inches deep with a plow that thoroughly turns over the furrows. It shall then be thoroughly cultivated, treated to a third coat of oil at the rate of one-half gallon per square yard, again cultivated, and then recrowned with a good road grader until the surface substantially conforms to the required cross-section. It shall then be tamped with the tamping roller until it is solid to within two inches of the surface. The contractor shall then provide and spread evenly upon the entire roadbed a layer two inches thick of gravel raked free from all stones that will not pass through a ring one and one-half inches in diameter.

The roadbed shall then be plowed or cultivated so as to thoroughly mix this layer of gravel with the top two inches of the natural soil of the street. Then apply the fourth coat of oil, amounting to one and one-half gallons per square yard of surface covered, spreading the same evenly over the entire surface of the roadway, and cultivate the same in thoroughly with a cultivator set so as not to disturb the tamped sub-base.

The roadway shall then be tamped with the tamping roller until the entire surface is uniformly hard, solid and free from undulations or other irregularities.

In the process of cultivating, the surface shall be gone over not less than ten times after each of the first two applications of oil, and not less than ten times after the third application, and in all cases until the oil and soil are thoroughly mixed.

The total quantity of oil to be applied on the street shall not be less than three and one-half (3½) gallons net oil by measure for every square yard of surface covered, and in all cases sufficient oil shall be applied to thoroughly coat the material of the street.

For the purpose of these specifications gravel shall be defined as a mixture of sound hard stone and sand. The stone shall vary in size from that which will be rejected by a screen of four meshes to the inch, up to the limit specified above, and shall contribute at least sixty (60) per cent of the total volume of the gravel.

At all stages of the work sufficient water shall be applied to secure the best results in the tamping, the amount of water to be used to be governed by the character of the soil, the intention being to make the soil just damp enough to pack solid.

Any portion of the street that can not be reached by the roller shall be tamped solid by hand, under the direction of the Board of Public Works.

The contractor will be held responsible for all damage to curbs, gutters or cross-walks that may be caused by him in the performance of the work.

Should an excess of oil remain upon the surface after rolling has been completed, sufficient clean, sharp, coarse sand shall be spread over the surface to absorb the same, and the surface shall then be again rolled until solid.

—4—

OIL.

(*a*) The oil used shall be a natural oil treated to remove water or sediment, or one from which the volatile material has been removed by distillation. It must not have been injured by over-heating.

(*b*) TEMPERATURE.—All oil must be delivered at the point required for sprinkling at a temperature of not less than one hundred and fifty (150) degrees Fahrenheit.

(*c*) Measurement: In determining the quantity of oil delivered the correction for expansion by heat shall be as follows: From the measured volume of oil received at any temperature above sixty (60) degrees Fahrenheit, an amount equivalent to four-tenths (0.4) of one (1) per cent for every ten (10) degrees Fahrenheit shall be subtracted as the correction for expansion by heat. For the purpose of measuring oil a temperature of sixty (60) degrees Fahrenheit shall be deemed normal temperature.

(*d*) Volatility: The oil shall not contain more than eight (8) per cent of matter volatile when said oil is heated slowly to two hundred and twenty degrees Fahrenheit and maintained at that temperature during fifteen (15) minutes.

(*e*) ASPHALT.—After being freed from water and sediment, the oil shall contain not less than seventy (70) per cent of asphalt, having at a temperature of seventy-seven (77) degrees Fahrenheit, a penetration of eighty (80) degrees, District of Columbia Standard. The percentage of asphalt shall be determined by heating a weighed amount of said oil in an evaporating oven to a temperature of four hundred (400) degrees Fahrenheit until it has reached the proper consistency, when the weight of the residue shall be determined and the per cent calculated.

(*f*) Water and Sediment: Deduction will be made for water and sediment in exact proportion to the percentage of water and sediment found therein, and the oil shall not contain over (2) per cent of such water and sediment.

(*g*) Tank Wagons: All tank wagons used for the delivery of this oil must be first submitted to the Department of Oil Inspection, which will gauge and stamp into the steel heads of said tanks the capacity in gallons of said tanks, and no figure of capacity will be accepted other than the official rating given by the Department of Oil Inspection

(*h*) All oil to be used shall be tested by the Department of Oil Inspection.

—5—

ROLLER.

The tamping roller to be used in the execution of the work herein specified shall consist of a roller, the outer surface of which shall be studded with teeth not less than seven inches long and having a surface area of not less than four square inches each, the roller itself to be of such a weight that the load upon each tooth shall not be less than three hundred pounds.

—6—

CULVERTS.

Culverts shall be placed wherever designated on the profiles or plans of the street on file in the office of the City Engineer. They shall be of the character and dimensions shown on the profile or plan and described in the specincations named in the Ordinance of Intention.

—7—

GENERAL REQUIREMENTS.

All work shall be executed in every respect in a thorough and workmanlike manner. The contractor shall preserve all stakes set for the lines, levels or measurements of the work in their proper places until authorized to remove them by the City Engineer, and any expense incurred in replacing said stakes which the contractor or his subordinates may have failed to preserve shall be borne by the contractor

Any overseer, superintendent, laborer or other person employed on the work by the contractor, who shall perform his work in a manner contrary to these specifications shall be discharged immediately, and such person shall not again be employed on the work All loss or damage arising from any unforseen obstruction or difficulties which may be encountered in the prosecution of the work, or from any action of the elements, or from any act or omission not authorized by these specifications, on the part of the contractor or any agent or person employed by him, shall be sustained by the contractor.

No work which may be defective in its construction, or deficient in any of the requirements of these specifications will be considered as accepted in consequence of the failure of any officer of the city or inspector connected with the work to point out said defects or deficiency during construction, and the contractor shall correct any imperfect work, whenever discovered, before the final acceptance of the work.

The contractor assumes all risk of variance in any computation or statement of amounts of quantities necessary to complete the work required by this contract, and agrees to furnish all necessary labor and materials, and to fully com-

plete said work in accordance with the plans and specifications, and to the satisfaction of the Board of Public Works

Bidders must examine and judge for themselves as to the location of the proposed work, the nature of the excavation to be made, and the work to be done

The contractor shall give twenty-four (24) hours' notice in writing when he will require the services of the City Engineer for laying out any portion of the work He shall dig all stake holes necessary to give lines and levels.

The contractor shall not disturb any monuments or stakes found on the line of the improvements until ordered by the City Engineer and he shall bear the expense of resetting any monuments or stakes which may be disturbed without orders.

The contractor shall remove at his own expense all obstructions, such as trees, stones, debris, etc., that may be in the way of making the proposed improvements.

No more than one cross street shall be closed at any one time.

The contractor shall observe all the ordinances of the City of Los Angeles in relation to the obstruction of streets, keeping open passageways and protecting the same where they are exposed and would be dangerous to public travel.

He shall also erect, and keep erected by day and night, a fence or proper barrier along the line of the work and across the ends of the same, in order to guard the public effectively from danger of falling into trenches, or from upsetting their vehicles against the earth thrown up during the progress of the work. and he shall post all proper notices and signals to the public of the state of the street while the work is in progress.

A red light must be maintained at night at each end of the barriers from sunset until sunrise, and a watchman employed as additional security whenever the same may be needed.

In case it should be necessary to move the property of any owner of a public utility or franchise, such owner will upon proper application by the contractor, be notified by the Board of Public Works to move such property within a specified reasonable time, and the contractor shall not interfere with said property until after the expiration of the time specified.

The right is reserved to the owners of public utilities and franchises to enter upon the street for the purpose of making repairs or changes of their property that may become necessary by the work The City shall also have the privilege of entering upon the street for the purpose of repairing sewers, or making house-drain connections therewith, or repairing culverts or storm drains

The contractor shall remove all surplus materials and rubbish from the work after its completion, and before he makes application for the acceptance of the work.

The contractor shall notify the Board of Public Works when he desires a final inspection of the work, when the latter will, as soon as possible, make the necessary examination. and if the work is found in compliance with the above specifications, the Board of Public Works will furnish the contractor with a certificate to that effect.

Whenever the word "Contractor" is used in these specifications, it refers to the party or parties of the second part in the agreement for the construction of the work herein specified.

Whenever the words "Board of Public Works," "City Engineer" or "Department of Oil Inspection" are used in these specifications, they refer, respectively, to the Board of Public Works, the City Engineer, or the Department of Oil Inspection of the City of Los Angeles, or their authorized agents or inspectors.

When in the specifications a maximum and minimum, either of size, percentage or thickness, or relating to quality or character, or other matter, is allowed or prescribed, the work shall be accepted as in compliance therewith, if within such maximum or minimum so allowed hereby

I hereby certify that the above specifications were adopted by the City Council of the City of Los Angeles, at its meeting of May 29, 1907.

H. J. LELANDE, *City Clerk.*

CHAPTER V.

SANITATION.

In many places of considerable size fifty dollars per month is the limit of cost set on hauling garbage and cleaning streets. Sometimes it is all that can be afforded. Sometimes it is believed the people themselves will do much to help themselves, and they do in fact make private contracts for work properly belonging to the city. The people who can afford it pay for such service. The poorer people who can not afford it take chances of illness and debility. The city permitting it also takes chances of pestilence.

Smells are not dangerous. They are rarely, if ever, a cause of illness. They are simply unpleasant to our modern sense of what is right and proper.

Insanitary surroundings are not the awful menace to health they once were thought to be. More is now known of such matters. Men whose business it is to clean sewers are robust in appearance and the work is not unhealthy.

Where the danger does come in, is that people who live in places surrounded by decaying matter in all stages of putrefaction do not breathe pure air. The constant breathing of this impure air lowers their vitality. When illness comes it attacks a system not calculated to bear up under the attack and the poisoned air is all the sufferer can get while ill, unless removed. Then the dirty place becomes a menace to the community.

Wells in crowded districts are not dangerous in themselves, for generations of people have used wells without harm. The dangers of filth coming long distances through the soil have been overrated. The danger in wells arises from the fact that there may be fissures in the earth through which harmful liquids may come, instead of slowly filtering through the soil and being purified en route. The bottoms of cess-pools may often be at the level of

the water bearing strata from which the neighborhood wells receive their supply.

While many fanciful tales have been told of the dangers of heaps of filth, and of wells as a source of water supply, the real truth is that they are simply a menace. If waste matters accumulate until decomposition has reached an advanced state, flies, rats, or some other pest may carry some of the matter to food and infect it or may carry it where it will be a poison to some one sick or in poor enough health to be dangerously affected.

If a person is ill with an infectious disease, the wastes and excreta may be placed in cess-pools directly connected with the water supply of a neighborhood. An epidemic is the result.

The pile of decaying matter may dry and innumerable fine, dust-like particles be blown by the wind into contact with a person affected with a slight skin complaint. The poison, coming into contact with an otherwise harmless and simple affection, may cause the disease to assume a contagious or infectious form.

Our ancestors lived for ages in the midst of filthy plague spots and drank from wells in the center of thickly populated districts. Districts populated with people who knew nothing and cared nothing about cleanliness. They lived through it, when, according to advanced sanitarians, they should have died.

Much remains to be learned about matter out of place, as dirt has been defined. We do know that perfect cleanliness pays from the sense of personal cleanliness it gives, if for no other reason. A sense of pride and right living go far toward making healthy surroundings.

Too much filth is always a distinct menace, and all cities should be willing to go to considerable expense to prevent its accumulation. The danger to cities comes from the herding together of poor people who must live near their places of employment. They live together too closely to get the full allowance of pure air necessary. Their habits are in consequence not cleanly, for they lack conveniences. The wastes of living in garbage, excreta, etc., are enormous in the aggregate, and unless frequently removed the already over-breathed air is badly polluted.

We are protected by micro-organisms. Organic matter under natural conditions is broken up by their aid. Roughly speaking,

there are two classes of active health protectors, known respectively as aerobes and anerobes.

Aerobes take up oxygen from the air. When organic matter is thrown upon the surface of the ground decomposition sets in readily, the air and moisture speedily propagating micro-organisms. The aerobic bacteria seize upon the organic matter, splitting it into simpler compounds, which are further oxidized by the air left by the organisms.

Rain water serves to renew from time to time the necessary moisture and carries remaining unoxidized matter into deeper layers, for the anerobes to complete the work so well begun by their brothers of the air-fed layers.

Anerobes secure oxygen from the complex organic substances which are split into simpler compounds by the abstraction of the oxygen.

It is believed that under certain conditions the two classes merge and anerobes may have been aerobes, changed because of environment. The two classes, however, are necessary. If balanced properly in numbers, as they will balance under proper conditions, heaps of filth will soon be rendered innocuous. If heaps of filth are constantly added to, then the aerobes are interfered with by a shutting off of their source of oxygen and the anerobes alone are left. Then we have smells.

Gases liberated by aerobes at once oxidize by the air, in the presence of moisture, into acids which combine to form salts with the various bases in the soil. The anerobic gases are thrown off and give rise to disagreeable odors.

When garbage and the wastes of living are thrown into thick heaps on a dumping ground the bacteria can only work on the surface. Down in the depths they can not exist and such heaps are a menace for ages. It is stated that matter was uncovered in Rome in spots that had been public dumps eighteen centuries before and much illness resulted.

The way, therefore, to dispose of garbage and waste matter is to put it where it can be treated by the proper scavengers in the right way—unless the city can afford a crematory.

When garbage is dumped on land it is merely as a make-shift. The custom is to place it on the ground and allow hogs to work

over it or, after awhile, plow it in, when it covers the whole area to a depth of several inches.

Engineering News, April 6, 1905, had an editorial on the subject, and the following facts were presented in favor of a systematic land disposal. The proposition is to bury all garbage on tracts of land far removed from habitations, under six inches of earth. By putting six inches of earth over the garbage a thickness of nine inches can be placed over the area. Then an acre of ground will take 32,670 cubic feet of garbage or, say, 600 tons. If we take the average annual production of garbage per 1,000 inhabitants at 75 tons, a city of 25,000 inhabitants would produce 1,875 tons of garbage per annum, which could all be disposed of on a field a little over three acres in extent, or a tract of thirty acres would last such a city for ten years.

A knowledge of the nitrifying and purifying properties of fresh soil assure one that such a plan can be adopted without offense. It is well known that even such highly offensive substances as spoiled meat and the bodies of dead animals, when buried in the earth with a cover of only a few inches of fresh soil, give off no offensive odor and are gradually resolved into their original elements, without offense.

Garbage, however, contains only a very small percentage of animal refuse. In a cubic foot of average garbage from an American city, from 70 to 80 per cent is water. When the water is removed it will be found that the bulk of the remainder is vegetable matter, rubbish and bones. Of grease and animal matter there will be not to exceed 5 per cent as a rule. It is conceded that all the vegetable matter in garbage will decay without offense under a very slight cover of earth, and it will be seen that the actual quantity of animal matter buried in the soil, even if we applied garbage to a depth as great as a foot, would be no considerable amount. It will also be evident that when the actual composition of garbage is considered, that while 600 tons to the acre may seem like a large amount to apply to land, it is so largely composed of water and vegetable matter that it can not possibly injure the land for agriculture by over-fertilization, especially if it is buried under a depth of at least six inches of earth.

The present way of covering a tract of land and then plowing it at infrequent intervals can not be too strongly condemned. The

way to do the work is to excavate trenches one foot deep and two to three feet wide. Commence with one at one side of the field and make it, say, 500 feet long.

Place the garbage in this trench and spread it to a thickness of about nine inches A trench of the size mentioned will hold about twenty tons of garbage. To cover this garbage excavate another trench alongside and use the fresh earth.

Engineering News then figured out on the above basis for a city of 25,000 inhabitants. For the purposes of this book we will figure it in a different way. Assume one pound of garbage per day per capita. For 1,000 people this will be half a ton. This is an extreme figure, but we will use it.

Assuming that a trench 500 feet long, one foot deep and from two to three feet wide, will hold twenty tons of garbage, we will require only twenty-five feet of trench per day for 2,000 people. This will be less than three cubic yards of earth to handle. As the soil on which such a plan can be best worked is easy to handle with pick and shovel, one man can be kept on the ground all the time. He can dig the new trenches and cover the old ones and assist the teamsters to unload. When it is seen that he is overworked another man can help him.

Before winter sets in calculate the number of trenches required to hold the winter garbage and have them excavated early. They need not be covered, for the garbage will freeze, but as warm weather approaches some earth can be brought in from a borrow pit and an inch or two can be spread over the trenches until the dirt piled alongside has thawed enough to be used.

As the city grows it will pay to dig longer and perhaps narrower trenches. Then each evening a regular road grader and elevator can be drawn down the side of the trench used that day and excavate a new trench while covering the old one. There are plows used in the Western States for breaking new ground. They cut a broad, deep furrow in a cut and cover style. Such plows might be used to advantage when the work becomes so heavy that manual labor would be too expensive.

After some considerable area is covered the earth should be harrowed and when a season is over it would be advisable to leave such land fallow a year. It might be harrowed early in the spring and the following fall plowed and the next spring be used for vege-

tables. If a town owned twenty acres of land it could use one or two acres per year in this manner and the land would be properly fertilized once in ten years or so with the garbage. The sludge from the sewage disposal plant could be placed with the garbage.

The best way to get rid of straw and manure is to spread them over the ground in thin layers to let moisture do its work. Occasionally, in a long dry spell, it can be burned. As the odor of burning straw is offensive when mixed with stable wastes the writer recommended to one town the purchase of hay choppers. The dry straw and manure, free from lumps, were then chopped up and spread over the ground to rot and enrich the soil.

Ashes and tin cans are not garbage and should be separated from it. Ashes make good filling for vacant lots, when clean. Tin cans and wires are a nuisance, and about the only thing to do with them is to use them also for filling, together with the ashes. They are not a menace to health at any rate, but are unsightly when piled on vacant lots. When dumped into hollows and ravines and gradually covered with ashes rust sets in and they are not troublesome in a few years when excavating is done on the spot. The writer recommends ashes in connection with tin cans and metal because the ashes from the average American home contain a great deal of unburned coal with a high content of sulphur. When wet this assists greatly in rusting and decomposing the metal.

Garbage should be collected in tight cans and hauling them through the streets will not be offensive. In Oakland, California, garbage is put in metal cans having tight fitting covers. Each can holds ten gallons and weighs, when filled, about fifty pounds. All the cans are brought empty, after being sterilized at the crematory, to the back yards and the full can is put in a specially constructed wagon and taken to the crematory. The great thing in favor of such a method is that the cans are regularly and thoroughly cleaned, the covers are never removed until the can reaches the place of final disposal, there is no leaky, bad smelling wagon traveling through the streets, and the wagon used is specially made for the work, so there is no rattling of the cans.

The use of ground for garbage disposal will hardly be considered after the town has become a large city, for the hauling of garbage long distances is expensive. The best method, when it

can be afforded is to install a first-class crematory and burn all garbage and waste organic matter. It is the only sanitary way

In England, where the character of the refuse is somewhat different from American refuse, a great many plants for burning refuse are combined with power plants to raise steam. The cost of burning garbage is thus reduced, as some of the expense can properly be charged to the fuel account of the power plant. The cost of the power plant is also reduced, as the garbage has a distinct fuel value, although slight. Analyses of American garbage and refuse seem to indicate that few of our cities can do much along this line. Therefore, little has been attempted in the production of power from the incineration of garbage. It may pay in very large cities, but in small places it is doubtful.

Waring gave the percentages of different substances in garbage as follows:

Rubbish	7	per cent.
Water	71	"
Grease	2	"
Tankage	20	"
	100	per cent.

The tankage amounted to 20 per cent or, say, 400 pounds in one ton. It yielded, upon treatment, 13 pounds of ammonia, 13 pounds of phosphoric acid and 3 pounds of potash. All of the grease was merchantable, so that while there was ten times as much tankage as grease, it only yielded, after expensive treatment, 29 pounds of acids. A table given in the same book shows the garbage to vary in different cites from one-quarter to nine-tenths of a pound per capita daily.

The idea of reducing garbage is dying hard. Some years ago it was all the rage, but today little is heard of it. There may be money in reducing garbage. We all know there is gold in sea water. The right kind of process must be efficient and cheap to get gold out of garbage or out of sea water. The largest item of cost in the disposal of garbage is the haul, which varies from 25 to 75 cents per ton mile.

For reduction only certain kinds of garbage are worth considering. As they occupy a small percentage of the bulk, it means hauling one hundred pounds of material to pick over and sort and

then run through an expensive process to obtain at the end two pounds of grease and not quite three pounds of different acids. No reduction works in America have paid without a subsidy of some sort and none can pay in a city of less than two hundred thousand people. Garbage contains more water and less grease in summer than it does in winter. It changes in composition from day to day, so a reduction plant must be located in a large place, where a certain amount of the right kind of garbage can be depended on.

Garbage is sometimes picked over even at incinerating plants, but no man can afford to pay pickers. They must do it themselves, like rag pickers in the alleys. In New York City a contractor did it, but this book is not written for places approaching New York in size.

There are many garbage burners in the market that can be placed in the chimneys of ordinary kitchen stoves. The hot air going up the pipe carbonizes the garbage without odor and the refuse can then be burned in the fire box of the stove.

A proper system for a small town should make it compulsory on every householder to provide himself with one of these carbonizers or with a tight garbage can in the back yard. Beside the garbage can should be one for ashes, rags, paper, etc. There should be heavy fines for mixing the contents of the two cans, or barrels.

Ashes should be hauled away at least once each week. Garbage should be hauled away at least twice each week in cold weather and once each day in summer.

The garbage should be taken to a lot and buried as already described or taken to a garbage incinerator and utterly destroyed. There are many fairly good devices in the market, but a city needs expert advice on the subject before investing, owing to the number of poor furnaces now advertised.

Streets and alleys should be kept clean. Paper and rags are not only unsightly, but they are a dangerous fire risk. Horse droppings should be taken care of also, especially on streets paved with impervious material.

Street sweeping pays and so does frequent street sprinkling. It is bad to have poison-laden dust blown into eyes or nostrils. Dust is bad, also for store keepers.

In a small place, the best a council can do often is to provide the land for the dump and men to look after it. Have a scavenger

whose business it will be to look after papers, etc., on the streets and then advertise each year for bids for carrying the garbage from the houses to the dump. Pass an ordinance fixing the maximum rate to be charged householders for taking away their garbage and grant the exclusive privilege to the man who will do it for the lowest price, and pay the city 5 per cent of the gross receipts for the privilege. This will insure the citizens getting good service and they can not be overcharged. Such work should be under the control of the Board of Health.

As soon as there are paved streets the street cleaning department should be enlarged. The one man and cart, with a spear to pick rags and papers, will develop into a corps of "white wings," constantly in evidence. Constant cleaning is better than a sweeping once a night or once a week. The cost of cleaning paved streets varies from 12.5 to 20 cents per 10,000 square feet.

The greatest expense in street cleaning, as in garbage disposal, is the haulage. It is good policy, therefore, to bear this in mind in designing sewers for a combined sewer system, or when designing storm water drains. The sweepings from the paved streets can often go directly into the sewers when they have a constant flow of a certain depth. This matter, however, is discussed in the following chapter.

A definition of terms loosely used by laymen seems necessary. Garbage consists of solid, organic household wastes and the organic wastes of living; non-putrefactive matter and street sweepings being termed refuse. Sewage consists of liquid household wastes and contained excreta.

PLUMBING WORK.

Every city official interested in sanitary betterment should procure copies of the following works of Wm. Paul Gerhard, C. E.:

Recent Practice in the Sanitary Drainage of Buildings, No. 93, Van Nostrand's Science Series. Price, 50 cents.

House Drainage and Sanitary Plumbing, price 50 cents, being No. 63 of Van Nostrand's Science Series.

The Disposal of Household Wastes, price 50 cents, being No. 97 in Van Nostrand's Science Series.

In No. 93 the following suggestions for a Sanitary Code appear.

A—RULES AS TO HEALTHFUL BUILDING CONSTRUCTION.

1. It shall be considered unlawful to erect, or cause to be erected, a new building upon any site which has been filled up with house refuse or any kind of animal or vegetable matter, unless such matter shall have been properly removed from such site.

2. It shall be considered unlawful hereafter to erect, or cause to be erected, any new buildings or structures of any kind upon any damp or wet site, unless such site shall have been effectually drained by means of suitable, properly laid earthenware tile pipes.

3. It shall be considered unlawful to lay such drain pipes in such a manner as to communicate directly with any drain carrying foul sewage, or with a sewer or cesspool.

4. The drainage of the subsoil of buildings shall conform to the following regulations and requirements:

a. The subsoil drains shall be laid, if possible, at a depth of not less than two feet below the cellar floor.

b. They shall be laid with open joints, protected against entrance of dirt or vermin by collars of clay or by paper or muslin wrapping.

c. They shall be laid on a true grade, with perfect alignment and with a continuous fall toward the outfall.

d. The outfall shall be either directly into the open air or into a ditch or road gutter.

Mr. Gerhard has the following note: If connection must necessarily be made with a sewer, arrangements shall be made for perfect disconnection, and the water seal of the trap must be maintained, even in the driest seasons, by suitable arrangements, approved by the inspector.

The writer changed somewhat the wording of paragraph d above. Section 5, following, has been changed also by the writer.

5. It is recommended that all cellar floors be made of concrete, not less than six inches thick, and that when the building is in a damp location that the concrete shall have incorporated in it a waterproofing medium or shall be treated otherwise with some waterproof compound. The cellar may be made tight by putting over the whole floor surface, before laying the concrete, a thickness of felt or tarred paper mopped with hot asphalt or hot tar or with some compound of each, and upon that a second layer also mopped with the same material.

It is recommended that every wall of new buildings be pro-

vided with a dampproof course of proper material, placed above the level of the ground, and also that the walls, to the height of the damp course, be treated with a waterproof compound or have incorporated in them waterproof material, or that on the outside of the wall, against the earth, there be placed several thicknesses of felt or tarred paper mopped as provided for floors.

It is recommended to whitewash the cellar walls of all buildings at least twice a year.

6. Buildings without basement or cellar shall be placed on brick or stone piers or posts, and the floor of the first story shall be raised so as to be at least two feet above the surface of the ground. There shall be a free circulation of air underneath the floor, and between it and the surface of the ground.

B—RULES AS TO CONNECTIONS BETWEEN HOUSE DRAINS AND STREET SEWERS.

1. It shall be considered unlawful to connect, or cause to be connected, any private drain with a street sewer without first obtaining a permit from the proper authorities.

2. It shall be considered unlawful hereafter to construct any drain for any building and to construct the same to any street sewer, unless the drain shall in its plan and construction conform to the following requirements:

a. Each building shall have a separate connection with the street sewer.

b. Wherever junction pieces have been built into the sewer, they must be used for making said connection, unless special permission is obtained to cut the sewer.

c. No pipe, or other materials for drains, shall be used until they have been examined and approved by the authorities, or their duly appointed superintendent or inspector. No house drain to be larger than five inches inside diameter, except by special permission.

d. No street shall be opened until the junction piece in the sewer has been located by the superintendent.

e. If no junction pieces are built into the sewer, a connection shall be made by inserting into a brick sewer (or concrete sewer—McC.) a junction pipe of proper size, and cut slant to an angle of forty-five degrees by the manufacturer. Great care must be

taken not to injure the sewer, and all rubbish shall be carefully removed from its inside.

f. In connecting a house drain with a pipe sewer, a Y junction (if none can be found—McC.) must be inserted in the line of the sewer, and the main sewer left in good condition.

g. In all cases the trench must be opened to the point of connection without tunnelling, so as to allow of an easy inspection.

NOTE—The above is an important provision if any thought is taken that there is danger of future settlement injuring the street surface. Thought must be taken of that as well as regard being had for easy inspection.—McC.

h. In opening any street or public way, all materials shall be placed where they will cause the least inconvenience to the public, and the whole enclosed with sufficient barriers, and properly lighted at night from the beginning to the end of the work.

i. The least inclination of the house drain shall be 1 in 60, unless a written permit is obtained to lay a house drain to a lesser grade.

k. When the course of the house drain is not the same as that of the junction piece, it must be connected therewith by a curve of not less than ten feet radius. All changes of direction to be made with curved pipe, and in no case must a pipe be clipped.

l. Every joint shall be laid with gasket and cement, and bedded in hydraulic cement at least four inches in depth.

m. The ends of all pipes not to be immediately connected shall be securely closed, water tight, and guarded against entrance of earth, with imperishable materials. The inside of every drain, after it is laid, must be left smooth and perfectly clean throughout its entire length, and true in line and grade.

n. The back-filling over drains, after they are laid, shall be puddled or rammed, all water and gas pipes protected from injury or settling, and the surface of the street made good within forty-eight hours after the completion of that part of the drain lying within the public way.

o. No privy vault or cesspool shall be connected with the house drain or sewer.

A PROPOSED PLUMBING ORDINANCE.

The following ordinance is in use in several places:

An Ordinance to regulate the plumbing and drainage of buildings in the ...... of ....

The Common Council of .... does ordain as follows:

SECTION 1. That all the work of installing new plumbing and drainage work in buildings erected, or to be erected, in the .... and repairs and additions to, and alterations of the plumbing and drainage of all buildings in said city, shall be done in accordance with the provisions of this ordinance, and of Ordinance No. ...., known as The Building Code.

SEC. 2. All connections of plumbing and drainage of buildings with the public sewers shall be made in acordance with the provisions of this ordinance and Ordinance No. ...., known as the Drainlaying Ordinance.

HOUSE DRAINS.

SEC. 3. House drains shall be of first quality, salt glazed vitrified fire clay, with perfectly smooth interior and exterior surface, except for three inches at the joint ends, inside the socket and outside where the pipe fits into the socket. The pipe shall have what are known as extra wide and deep sockets.

House drains of tile shall terminate five feet from the building line and from that point to the inside of the house shall be of first quality cast or wrought iron pipe. Where said pipe comes in contact with the earth it shall be coated with some approved process or rustless coating.

The joints of tile drain pipes shall be filled with cement mortar with one inch of cement dipped, hemp gasket driven in and the joints of iron pipes shall be well caulked with lead and made air and water tight.

The house drain shall not be laid below the cellar floor, except where absolutely necessary, and in this case it shall be laid in a trench and shall be surrounded with concrete. The trench shall be filled and closed after the drain is thoroughly inspected and pronounced tight.

All connections in horizontal pipes to be made with Y branches.

VENTILATION.

SEC. 4. (a) When connections are made to old and improperly constructed or foul street sewers, or to cesspools or vaults, the house drain shall be trapped, near the point where it leaves the building, by a running or half S trap, which shall not be larger

in diameter than the house drain. This trap shall be placed in an accessible position, protected against freezing, and must be provided with an inspection hole, and a tightly closing cover.

(b) There shall be a fresh air inlet pipe, entering the house drain just inside the main trap, of a diameter not less than four inches, and opening at any convenient place out of doors, approved by the inspector; provided, however, that when the said trap is not required the fresh air inlet shall be omitted.

(c) When connection is made to well constructed sewers, having a self-cleansing flow and adequately ventilated, the above trap shall be omitted and the plumbing so arranged that in every house connected with such a sewer there shall be an uninterrupted flow of air passing from the sewer up the house drain and soil pipe and out at the roof.

(d) All soil and waste pipes shall be run in as straight a manner as possible up to and at least five feet above the main house roof. Soil pipes to be enlarged to six inches and waste pipes to four inches above the roof. The upper terminus shall not be located within five feet of a window, ventilating shaft or chimney flue. The outlet above the roof shall not be capped by either a return bend, ventilating cap, or movable ventilator.

(e) Extensions of soil or waste pipes shall not be constructed of sheet metal or earthenware, and no soil, waste or vent pipe shall stop in any brick or earthen chimney flue, serving as a ventilator.

GENERAL PIPING.

SEC. 5. (a) No soil pipe shall be larger than four inches, and no waste pipe larger than two inches inside diameter (their extensions above the roof excepted).

(b) Waste pipes for fixtures to be in size as follows:

	Inches inside diameter.
Wash bowls	1¼—1½
Bath tubs	1½—2
Pantry sinks	1¼—1½
Kitchen sinks	1½—2
Laundry tubs	1½—2
Slop sinks	2—3
Urinals	1½—2
Row of basins, tubs or urinals	2—3

No deviation from these sizes permitted unless specially authorized by the Inspector of Plumbing.

(c) All soil and waste pipes shall be kept outside of walls or partitions, and the system arranged in such a manner that it may at all times be readily examined and repaired.

(d) Every fixture in the house shall be separately and effectually trapped by a seal retaining trap placed close to the fixture, and arranged so as to be safe against back pressure, self siphonage, loss of seal by evaporation or siphonage.

(e) Wherever vent pipes are used, the branch vent pipes for water closet traps should be not less than two inches in diameter. All other traps to have vents the same area as the trap. The size of the main vertical lines of vent pipes will depend upon the height of the building and should also increase with the number of branches which they receive.

Where back air pipes are carried through the roof, they must be enlarged to four inches, to prevent clogging in winter time. All horizontal air pipes must be so graded as to discharge the water from condensation into a trap or waste pipe. T-branches on upright vent lines must always be set at such a height above floor that the branch vent can not act as an overflow pipe in case the waste should be stopped up.

(f) No branch waste pipe for tubs, sinks or basins to be larger than one and one-half inch diameter.

(g) Connections of lead pipes with iron hub pipes shall in all cases be made with heavy brass ferrules properly soldered to the lead and well caulked to the iron pipe.

(h) All joints between lead pipes, whether for supply or waste pipes, to be wiped soldered joints; cup joints not to be made anywhere.

Joints between lead pipes and brass fittings to be wiped solder joints; joints between lead pipes and brass couplings may be cup joints.

(i) Vertical iron pipes shall be as follows: Not to exceed two stories in any building can have standard iron pipe; not to exceed three stories shall have heavy iron pipe; below, the pipe shall be extra heavy.

(j) All rain water conductors which are carried up within the walls of a building shall be of iron pipe. Connections with such

rain water pipes along their vertical course, for the discharge of sewage or waste water therein, will not be permitted. Rain water conductors shall be trapped if they open at the top near windows, ventilating shafts or flues.

GENERAL PROVISIONS.

SEC. 6. (a) Every water closet shall be adequately flushed with water from a special flushing cistern arranged directly above it, except that where a cistern is liable to freeze other methods may be permitted, provided that thorough and sufficient flushing is secured. Every water closet apartment shall have direct means of ventilation into the open air. Pan closets shall not be permitted in any building. The outlets for single water closets shall not be larger than three inches in diameter.

(b) No opening shall be provided in the house drain for the purpose of receiving the surface drainage of the cellar, unless special permission is previously obtained and the directions followed.

(c) It shall be unlawful to throw or deposit, or cause or permit to be thrown or deposited, in any vessel or receptable connected with a public sewer, any garbage, hair, ashes, fruit or vegetables, peelings, or kitchen refuse of any kind, rags, cotton, cinders, or any other matter or thing whatsoever, except faeces, urine, the necessary closet paper, and liquid house slops.

(d) Waste pipes from refrigerators or other receptacles in which provisions are stored, shall not be directly connected with a drain, soil pipe or other waste or sewer pipes, but shall be made to discharge over an open tray, provided with a waste pipe and seal-retaining trap.

(e) Drip pipes from safes, under any kind of plumbing fixtures, must not have any connection with any soil, waste, or drain pipe.

(f) Overflow pipes from water tanks shall not be connected to any soil, waste, or drain pipe.

(g) No steam exhaust shall be directly connected with any soil or waste pipe or drain communicating with a street sewer.

(h) An approved form of grease trap must be placed on every sewer connection leading from dwellings, hotels, restaurants and buildings in which a sink is located. For one sink the grease trap

shall be not less than eighteen inches in diameter and it shall be increased proportionately to the number and size of sinks. The minimum dimension for a restaurant or hotel shall be thirty-six inches in diameter. The grease trap may be constructed of vitrified ironstone tile pipe with a six-inch Y attached and so set that the Y will point upward and be connected to the main drain by means of a manufactured curved pipe (chipping of pipes to make a bend is prohibited) in such a manner that a trap will be formed. The depth below the bottom of the outlet hole shall be equal to the diameter of the grease trap basin. The inlet shall enter the grease trap basin above the level of the top of the outlet and shall terminate in a right angle bend two inches below the curve forming the trap in such a manner that there shall be at least two inches seal. Across the middle of the basin shall be a thin iron plate, the bottom of which shall be six inches below the bottom of the inlet and the top of which shall be two inches higher than the bottom of the inlet. This plate shall be between the inlet and outlet openings. The grease trap may be covered with wood or any other material and shall have the grease skimmed off every day. The basin shall be cleaned as often as directed by the Inspector of Plumbing, but not less than once in seven days.

(i) When the grease is unusually plentiful from any kitchen the Inspector of Plumbing can order placed, at the expense of the owner of the building, a grease strainer, of approved design, in addition to the grease trap. This strainer to be cleaned whenever directed, but not less than once in seven days.

(j) Livery stables and barns with floors for cleaning vehicles, etc., shall be provided with sand boxes of approved pattern and same must be kept in efficient working condition.

(k) Before granting a permit to install the plumbing work in any building the Inspector of Plumbing shall carefully examine the plans. He shall cut out all superfluous pipes and see that the arrangements are as simple as possible, consistent with the best practice. He shall prepare, or procure from competent authorities, drawings illustrating all the standard connections and arrangements pemitted and keep same on file in his office for the inspection of the public. Copies of said drawings shall be furnished at the actual cost of reproducing to all registered plumbers upon request.

(1) All materials used shall be of first quality and the In-

spector of Plumbing is authorized to make such tests as he sees proper in order to determine the quality of the said materials.

(m) Before the fixtures are placed in connection with the pipe system, and before the soil pipe and iron house drain are connected with the outside drain, the outlet of the house drain and of all its branches shall be closed tight and the pipe filled with water to its top, and every joint shall be carefully examined for leakage, and all joints shall be securely closed before connections are made with said pipe system. The water test shall be applied before the pipes are built in or covered if there are any places where they require to be hidden. The water shall remain in the piping system for at least twelve hours.

SEC. 7. The plumber shall give the Inspector of Plumbing at least twenty-four hours' notice when he is ready to test the piping system. It shall be the duty of the Inspector of Plumbing to see that the pipes are filled with water within that time or forfeit to the plumber five dollars for each and every twenty-four hours' delay beyond that time.

(The rest of the sections of this ordinance can be filled in to suit local conditions. They should fix the officers, the fees, the penalties, etc.)

The writer believes a provision like the following should appear in every sanitary code or in every plumbing ordinance:

SECTION —. Whenever a public sewer is laid past a house it shall be unlawful to maintain any cesspool or privy vault for more than sixty days thereafter within two hundred feet of said sewer. Such cesspools and privy vaults shall be cleaned out and refilled with clean earth and the building shall have sanitary closets and sinks installed and connections shall be made with the said sewer.

CHAPTER VI.

DRAINAGE AND SEWERAGE.

DRAINAGE.

A distinction is made by engineers between drainage and sewerage.

Drainage applies solely to the disposal of surface and sub-soil water. That is, to water which can be put in any stream without danger of polluting it.

Sewerage, having to do with liquid wastes, containing putrefactive matter and matter containing germs and micro-organisms harmful to the human system, has to be considered apart from drainage.

In the majority of cases the drainage of a town offers few difficulties. The whole practice is simple. Keep the water on the surface as long as possible in easily controlled channels and dispose of it in the most convenient stream or river. It is only harmful when allowed to collect in low lying places, where it will become stagnant and provide a breeding place for harmful insects and germs.

The first step in drainage is to provide broad, deep gutters along the sides of streets, before or after grades have been established. Before the grades are established the gutters are merely ditches. After the grade has been established the gutters can be made of stone, as described in a previous chapter, or of brick or other material that will not wash readily.

On steep hill side streets, where an earth ditch would wash badly, and on streets where a great deal of excavation must be done before a gutter can be made on the official grade, temporary wooden V flumes are used. Sometimes wooden flumes with rectangular cross sections are used where a V flume would be too small. Great care has to be exercised in making the joints in wooden gutters. Underneath there should be laid a piece of wood for each section to be nailed to. On each side there should be a post driven deep into the ground, spiked to the flume.

Across from post to post, underneath the flume, should be a board about six inches wide, and on each post there should be a piece one foot wide, projecting like a wing. The space should be filled with fine gravel or broken stone, tamped hard. If water then follows the ground alongside the flume it will be turned into it wherever such obstructions are met. The flume boxes should be not more than sixteen feet long. Ten feet makes the best length.

When surface water is taken underground it is a source of expense and causes trouble whenever the conduit is choked. Therefore, keep it as long as possible on the surface and arrange the drainage system so the streams will be divided at every street intersection and sent in different directions to guard against too great an increase in flow and consequent difficulty in handling.

Much of the rain-fall is absorbed as it falls. As a town becomes more closely built over and the area of paved streets increases, a less quantity of water is absorbed and proper underground conduits must be provided for drainage. When the town becomes a city then a portion of the sewerage system will have to be of large sewers, sufficient in size to take care of surface and subsoil water, in addition to the sewage. This is discussed in the next chapter.

The slope of the streets and the crown placed on them form part of the drainage system of every town. In carrying the water across the streets it must go underground. It is not good to have a gutter continue across a street intersection with a bridge over it, or a culvert only fifteen or sixteen feet long under the roadway. It is not nice looking, nor convenient or healthful.

In some text-books on roads and municipal work the authors condemn the practice of having a small catch basin at the end of a block with a pipe across underneath the intersecting street. The writer, however, has built them that way and found no objection to their use. Sometimes nothing else can be done. In irrigated sections, where small ditches flow in the gutterways, it is the only way water can be carried across a street.

In such cases, the benefit of a sidling street is great. A difference of one foot in elevation between curbs is seldom noticeable without an instrumental determination, while it does permit of easy drainage.

The depth the pipe is placed below the surface depends upon the material. There should be not less than one foot of sand on top;

therefore, such a conduit is best placed under a cross-walk. If in a climate where the temperature varies in wide limits, the conduit should be of iron or reinforced concrete. Otherwise, of double strength vitrified pipe.

At the higher end put a small catch basin in the gutter. The bottom should be about two feet below the bottom of the pipe and there should be a metal bucket fitted inside so it will permit of easy cleaning. The pipe should run across the street and at the lower end be turned up into the gutter at an angle instead of terminating in a vertical well. The end can come up under the cross-walk, over the gutter.

The well at the upper end should have a grating over it. As horizontal openings are easily clogged with paper, rags and leaves, the grating should have vertical openings. The writer has often placed the wells under the cross-walk and put the grating at an angle of forty-five degrees over the end of the well, leaning against the top of the walk. When the water rises it has a tendency to lift obstructions and flow underneath into the well.

When combined sewers are used to carry both storm water and sewage, catch basins are a necessity on all streets. Rather, inlets are necessary; for there is a difference.

On streets that are not paved, or are simply improved with some material that wears and furnishes silt and dirt to go into the sewers, the inlets must be of a form that will allow the storm water to enter the sewer and will leave the dirt in a basin, to be cleaned out after a storm.

An inlet may therefore be simply an opening into a pipe that conducts the water to an underground conduit or it may be a part of a silt well or catch basin.

Silt wells and catch basins are fine in theory. Practically, they are too often a delusion and a snare. If cleaned after every storm they are proper adjuncts to a sewer system. If left without cleaning, as is too often the case, they are a nuisance and a danger. The writer knows of cities where thousands of catch basins have not been cleaned in twenty years. Some places the statement is made that the average time between cleanings is three years. He is, therefore, strongly of the opinion that when a street is paved with wood, brick, stone, asphalt or bitulithic material, catch basins

should be abolished and a simple inlet provided, with a running trap at the lower end, the inlet pipes to terminate in manholes.

The writer has raised storms of protest in places where he has advocated this. His only answer has been to refer the objectors to the street or sewer cleaning departments for figures. It has been found that in the majority of cities little attention is paid to thorough cleaning of silt wells and catch basins because of the great expense involved. The most that is done is to poke an opening under the trap when the basin is obstructed during a storm.

The usual form of basin is a square or circular well of brick or concrete with a pipe leaving it near the top. A brick or concrete wall, or metal plate, as a partition across the well at the top, the bottom of the partition being a few inches lower than the bottom of the pipe, forms a trap.

The dirt is washed into the basin with the water and is supposed to remain in the bottom while the water goes under the trap wall, through the pipe into the sewer. When the cleaning of the catch basin or silt well is omitted, or is an infrequent occurrence, the dirt from only the first storm is retained in the basin. The dirt in after storms goes to the sewers.

If the sewers are designed with a minimum flow of three feet per second they will carry the material to the point of disposal. If it has to be dredged and taken away from time to time, dredging is cheaper than shoveling into wagons and hauling away.

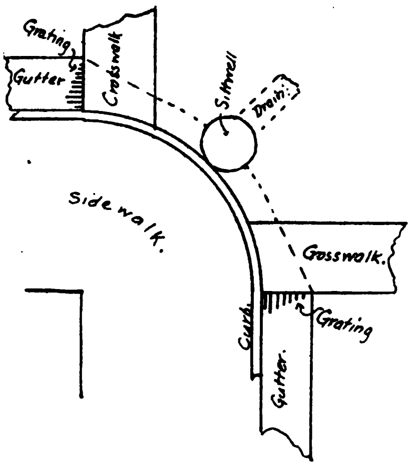
A simple inlet therefore on streets having good impervious pavements, with a running trap near the sewer, serves all the purposes of an efficient inlet.

The writer is anxious to collect all the information he can on this subject of catch basin and silt well cleaning and will appreciate all data sent him. Readers will please bear this in mind when annual reports are issued. If any reader cares to investigate conditions in his own town and report to the writer, such kindness will be gratefully acknowledged.

Before leaving this subject the writer wishes to add that such practice is only advisable where the sewers permit the material to be carried readily to the point of disposal. They must have sufficient grade to always have a self-cleansing flow and must be in good condition. The practice of having the street refuse go directly into the sewers should not be allowed where it is possible to clean

the streets by some cheap method and where catch basins can be kept clean at low cost. If the sewers are properly designed for such work it will be found that the cost of keeping them clean will be less than the extra cost of cleaning streets and catch basins with shovels and teams.

Silt wells, where used, should always have a metal bucket a few inches in diameter smaller than the well. Lying on the top rim there should be a cone shaped ring having the largest diameter a trifle smaller than the well and the smallest end a trifle smaller than the diameter of the top of the bucket. This will prevent material falling between the bucket and the sides of the well to bind it in place. When the ring is lifted the bucket can easily be hoisted and emptied into a wagon. The bottom of the well can then be cleaned and the bucket and ring replaced.



An approved form of inlet connection at corners. This does away with one basin and crossing of streets may be almost level.

Fig. 5

Many forms of inlet covers are on the market and it will seldom pay an engineer to get up plans for a local foundry, for the manufactured article can be shipped anywhere the freight rates are not excessive. Where the freight rates make it costly to buy from factories the engineer can design inlet covers for the local foundry to make.

It is usual to place the inlet on the curve of the curb half way between the cross walks. This means carrying the gutter around the corner and makes a depression for wheels to settle into when a vehicle is rounding the corner.

The writer prefers to have a vertical inlet grating at each cross walk and a pipe following the curb to a point half way between the cross walks. At this point the two pipes can meet in a well having an iron grating cover. From this well an outlet pipe can run to the manhole in the center of the street intersection. Even if a silt well is not located here it is a good idea to have a chamber admitting of easy inspection and with the bottom shaped to permit of a proper junction of flow.

With such an arrangement at street intersections all cross walks can go over the gutters on a level with the curb and the gutter around the corners need be only three or four inches high, simply enough to assist in guiding a wheel if a vehicle comes too close. Such a street intersection looks well if the curbs are joined on a circle of large radius.

Wood is a material often used for first temporary underground drains. Wooden boxes should be square and set on edge, making a diamond-shaped conduit. This is a good form that will always have a self-cleansing flow.

The use of wood is justified when the town needs the drains badly and is short of funds. It is justified when it is impossible to predict the direction or extent of future growth of population in a town likely to be subject to periods of boom growth, and the direction and location of main drains may be subject to change Wood should not be used when sewage is carried. Neither should it be used when a pipe twelve inches or less in diameter will do the work.

Vitrified pipes are most commonly used. When put less than five feet in the ground they should be of double strength. Pipes up to three feet in diameter can be obtained from almost all manufacturers. They are smoother and have greater capacity than brick sewers of equal diameter.

Brick is generally cheaper than vitrified pipes in all diameters exceeding thirty inches. Ordinary house brick should not be used, however. Use only vitrified or clinker brick for the lower half and a good hard brick for the upper half. The thickness of brick

sewers up to three feet in diameter may generally be one ring of brick (4½ inches), although some engineers use two rings for all sewers over two feet in diameter. From three to six feet, two rings generally suffice. Three rings, up to eight feet. Four rings, up to ten feet, and generally one additional ring for each nine inches or less increase in diameter.

Concrete was once used for sewers and drains, but fell into disfavor. Within the past five years it has come again to the front—this time to stay. More is known of concrete today and better work is done with better materials than was the case thirty years ago. Concrete sewers built in place are not so good as those built on the bank and lowered into place when thoroughly seasoned. The interior of a concrete sewer is theoretically smoother than the interior of a brick sewer, but if constructed in place with removable forms it is not always possible to get good workmanship. Contractors do not like to build them, for it is a gamble moving the forms.

The writer prefers for concrete sewers to have them built on the bank and placed in position in sections after thorough curing or to build the lower half of well cured blocks and the upper half on forms. The forms should be left in place a long time and considerable filling should be in place a few days before the forms are removed. In this respect brick sewers have an advantage, for the forms can be removed almost immediately after the last brick is in place and settling is taken care of in the joints.

Brick sewers, however, are inferior to properly constructed concrete sewers in other respects and the bricklayers' unions are becoming so hard to deal with that the writer believes brick sewers are apt to almost disappear in a few years.

An empirical rule for the thickness of concrete sewers is to make the minimum thickness five inches when no steel reinforcement is used and four inches when it is used. For sewers not reinforced the thickness should be in inches equal to the diameter in feet, plus one inch. For reinforced sewers the thickness should be in inches equal to the diameter in feet, minus half an inch, due regard being paid to the minimum thickness above mentioned. The reinforcement around the pipe should be equal in area to one per cent of the area of the concrete, taking a longitudinal section.

The longitudinal reinforcement should be one-third of one per cent of the area of the ring or cross section. However, for larger sewers careful calculations should be made.

When the word sewers is used drains of course are understood for the foregoing matter relates to both.

SEWERAGE.

Sewerage generally waits until water supply has been attended to. Modern sewerage systems contemplate water carriage of wastes and if the town has no public water supply sewers are not needed. Drains are all the people need.

The subject of sewerage can, however, be as well taken up after drainage as to wait until water supply is discussed.

At the time the plan for surface drainage is prepared, plans for a sewer system should likewise be adopted. It should not be a matter of haphazard growth, but should be gone at properly. Because a complete plan is prepared it does not mean it will all be constructed at one time, but simply that as sewers are put in they will be of the right size and put in the right place. In a growing place the work is never complete, but sewer building is going on all the time. Plans prepared must take this into consideration. Laterals can generally be planned of the right size, but the mains will be rebuilt or replaced by larger ones as the city grows. Having complete plans in advance fixes the lines of the main drainage and insures economy. As the grades on streets govern location of drains as well as sewers, a complete plan at the beginning of things shows where it will be possible to keep surface water and sewerage separate and where it will be best to combine them.

It has unfortunately happened many times that for lack of proper attention to this matter of getting plans early many private sewers have been built by well-to-do people. When a proper plan is at last prepared it has been found impossible to use these sewers in a general system and expensive lawsuits and vexatious delays resulted.

Vested interests always cause trouble. If a good plan for sewerage and drainage had been prepared early enough the private sewers

could have been constructed in a manner and in locations satisfactory to the council, and when a public system was installed they could have been purchased and thus been a benefit instead of a drawback when the city got around to that part of the work.

The term "sanitary sewers" is applied to small pipe systems designed to carry off household wastes alone, without surface or subsoil water. Such a system is also known as the "separate" system of sewerage. It is the only system to use in very small places and can in fact be kept apart from a storm water system until a city is quite large.

An ideal method of sewering and draining cities is to have two distinct systems, one for sewerage and one for drainage. This is costly, however, when a certain limit in sizes of mains is reached, so when a point is reached in the devolpment of a city requiring the drainage water to be taken underground the combined system should be installed.

By keeping the surface water in gutters for as long a time as possible, a distinct saving in sewer construction is effected. By having two entirely separate systems many expedients can be adopted to save cost. Storm water sewers are large and are only needed when a storm comes. They can, therefore, be placed at shallow depths. The writer installed one system by making shallow semi-circular conduits inside the curb line and sidewalks were built over them. At regular intervals gratings placed in the curbs admitted water to the storm sewers.

A small place contemplating the building of a combined system at the start may go without sewers for many years, for large sewers cost money.

In planning sewers for a sanitary system it is necessary to have the pipes large enough to flow half or three-quarters full with a velocity of about two and one-half to three feet per second. They will then keep themselves clean. If built of too large a size to carry a flow of constant depth at the proper velocity the sediment in the sewage will be gradually deposited until the sewer is choked. A small channel is left at the top, sufficient in size to carry the constant flow and no more. If this sewer is intended to carry storm water it will be found to be choked with decaying matter and refuse when the storm comes and the street is flooded until the sewer is cleaned.

In addition to the choking up of the drain and thus rendering it unfit for its purpose as a storm drain, the continual deposit of excremetitious matter is a menace to health. The large empty spaces invite accumulations of noxious gas, and odors, annoying in every way, get out into the open air. It is commonly believed that a sewer can not be too large, but more trouble is caused by sewers too large than by those barely large enough which occasionally prove too small in time of big storms. A small sewer is annoying once in a while and occasionally causes damage to property by reason of its inability to carry off a large rush of water in a short time. A sewer too large is always dangerous, not alone to the pocketbook but to health.

When sewers become choked it is usual to flush them with a hose attached to the nearest hydrant. Take a 15-inch pipe as an example. Disregarding decimals, the area is 177 square inches. The area of a stream of water from a 2½-inch hose is 5 inches. For flushing purposes it is useless. If there are no flush tanks on the line a wagon is sometimes used. Such a wagon usually has a tank containing from six hundred to one thousand gallons of water and with a twelve or fifteen inch opening at the bottom with a flap cover. This wagon is driven over a convenient manhole and the flap opened. The water goes in with a rush and such flushing is really efficient for some distance.

The minimum grade has already been referred to as one sufficient to produce a velocity of from two and one-half to three feet per second. A lighter grade will produce such a sluggish flow that solid matters can not be moved and so remain to clog the pipe. Too steep a grade produces so rapid a flow that solid matters often are stranded because the flow is not deep enough to float them. Either extreme is bad. A maximum velocity should be about eight feet. When the grade of the street is such that a greater velocity will be obtained the sewer should be run on a grade to secure not more than five feet per second and when it gets too near the surface drop a manhole to a greater depth and start another section of sewer from the bottom of it. This stepping of the sewer down hill can be accompalished by vertical drops in manholes or by the use of tumbling chambers. where the sewage falls over a flight of stone or concrete steps.

In the separate system small pipes must be used and it often

happens that a three or four inch pipe would be amply sufficient for the work. Such small pipes however, choke too easily and are difficult to clean. Therefore, the smallest size should be six inches. The writer has found from experience that it is unwise to make any line of six inch sewer more than six hundred feet long. The late Colonel Waring was an extreme advocate of six-inch pipes and has left his impress upon the minds of many text book compilers. His real argument was economy. The difference in cost between a six and eight inch pipe is small and the cost of excavation, laying and backfilling in each case is the same. For the slight difference, the eight inch pipe is preferable.

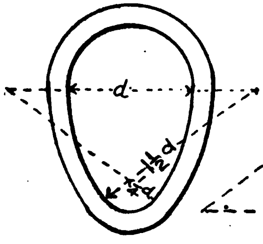
Until the population has grown sufficiently to keep a constant cleansing flow in the pipes a flush tank is a necessity in some localities. Flush tanks are generally considered a necessity in separate systems.

A flush tank should be capable of discharging from 60 to 300 gallons of water in less than one minute into a sewer and should be adjusted to discharge at least once each day. There are many patterns on the market. In general their advantages may be summed up as follows: The sudden discharge of a large volume of water into a small pipe momentarily compresses the air in front and forces it out at every opening.

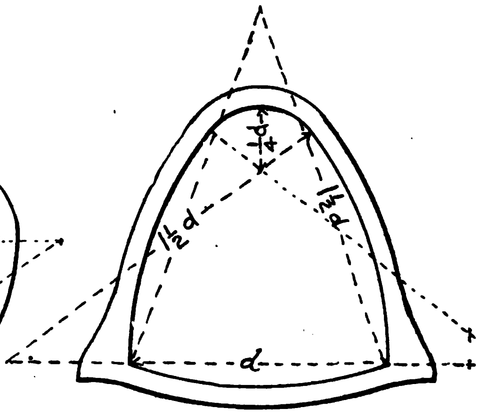
This creates a temporary vacuum which is filled with fresher air from the outside and thus simplifies the question of ventilation. The frequent volumes of cool water thrown in, together with the consequent changing of the air tends to keep the temperature of the sewer at a safe point. Disease germs can not multiply to any extent in a temperature less than sixty degrees Fahrenheit, and the ordinary temperature of a sewer seldom falls below sixty degrees. Flush tanks. therefore, serve a useful purpose by cooling the sewers to some degree and by making a steady temperature impossible.

Articles occasionally become stranded in a sewer and the sudden discharge of water in large quantities into the pipe starts them to moving This tendency of sewers to fill up until they obtained a cleansing flow was the primary reason for the adoption of flush tanks. The other benefits were noticed after they were in common use. In all sanitary sewers having a slow velocity of flow a

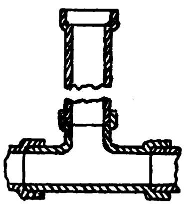
confervoid growth attaches itself to the sides just below the line of constant flow. The flush tank helps loosen this growth also.



Egg Shape Sewer.
Fig. 6.



A strong form of conduit in general use.
Fig. 7



Inspection holes—also called Lamp holes—are also occasionally set on a slant from a Y instead of a T.

Fig. 8 Inspection Hole.

In a sanitary, or separate system, manholes are placed at the end of each block and at the junctions of sewers and at changes in grade. They are thus frequently six or seven hundred feet apart. Inspection holes are often placed between manholes. They are simply pipes terminating a foot or so below the surface and arranged so they can be opened to inspect the sewer if a stoppage occurs. Sometimes the inspection holes are placed at an angle for the easy introduction of a rod for cleaning. As sanitary sewers

are not intended to carry silt or heavy solids a saving can be made in manholes. No catch basins, inlets or silt wells are needed on the streets. Occasionally roof water is admitted to them with the idea of giving them a thorough cleansing in time of storm. The introduction of rain water should be carefully regulated, however, or the sewer system may be taxed to do its work.

A surface drainage system requires manholes and so does a combined system at frequent intervals. Where the grade of a street is less than 3 per cent (three feet in one hundred feet) manholes should be placed about one hundred and fifty feet apart. On a five per cent grade they can be five hundred feet apart. For ease and convenience of cleaning, however, they should never be more than three hundred feet apart on sewers more than twelve inches in diameter.

In putting down a sewer system attention should be paid to depth. For a residence district the depth should be such that cellars can be readily drained. Therefore, in making a survey it is well to take elevations on the floors of all houses and measure the depth of the cellar. The sewer should be deep enough to allow a drop of one foot in one hundred feet from the bottom of the cellar to the top of the sewer. When profiles are made of streets the profile of the bottoms of cellars should be marked also. It will generally be sufficient to allow a depth of seven feet below the street grade for the tops of sewers in residence districts and a depth of at least ten feet in business districts. A depth of twelve feet is better in a business district. Sometimes in flat sections there is a discussion as to whether to put in a long sewer on a slight grade or construct several outlets with many short mains and short laterals. Such matters had better be left to the engineer who plans the system, presuming, of course, that he has been selected for his proven ability in such work. Baumeister says: "In general, the question of a system of complicated sewers is not solved by laying a number of equally important lines, but by leading the drains to a common center. It is cheaper to build a single system of nx capacity than n systems of x capacity."

In the separate as well as in the combined system all sewers should summit at manholes in order to provide ventilation. If a dead end can not be avoided it is a good plan to have a manhole or inspection hole there with a perforated cover. Underneath the

cover a pan should be suspended to catch dirt and dust. Sometimes an iron pipe connects the end of the sewer with a leader up the side of a house to get a high altitude in order that the warm sewer air in ascending will create a current throughout the system.

Today in many states the laws forbid the pollution of streams with raw sewage. This calls for some preliminary treatment and as it costs money and the filter beds, etc., occupy considerable area it is advisable to reduce the amount of sewage to a minimum. This is another argument in favor of the separate system.

However, the liquids can sometimes be separated satisfactorily and therefore it is not necessary to run two systems side by side after the constant flow of sewage is large enough to half fill a twelve-inch pipe. An egg-shaped sewer can be built with a section small enough at the bottom to carry the constant flow of sewage and the top afford space for the rush of storm water. The egg-shaped sewer should be laid at a grade which will give the smaller section a cleansing velocity when flowing six inches deep. This gives also a sewer that a man can enter to clean when necessary. The limit on size of an egg-shaped sewer may be said to be about ten feet in height. After a sewer of greater capacity is required the circular section can be resumed or the horseshoe section adopted.

At a point where it is desired to separate the sewage from the storm water a separator can be placed and the storm water taken to the usual place of disposal while the sewage goes to the treatment works. Such a separating chamber provides for taking care of all the water flowing to a certain depth in a sanitary sewer. When it exceeds this depth the surplus flows away in the storm sewer. The matter is generally arranged by providing for a certain amount of dilution of the sewage. This may be taken at from three to four. That is, when the volume flowing in the sewer exceeds the ordinary flow three or four times the excess can be taken away in an overflow.

Sewers should be so laid that the bottoms of house connections enter at the middle of the sewer. This permits a flow of half the depth, without eddies that would otherwise be caused by the side pipes. In connecting two sewers of different diameter it is customary to have the tops inside at the same elevation. This prevents deposits in the smaller sewer when the larger sewer is flowing deep. All junctions of sewers should be made in manholes and the

bottoms should be shaped to the bottoms of the sewers and with curves having a radius equal to about twice the diameter of the entering pipe. House connections should always be made by "wyes" attached to the pipes at an angle. No connections at right angles should be permitted. An inspector for the city should inspect every connection made.

Sewers need cleaning at intervals even when equipped with flush tanks. The cleaning should be done in the fall before winter rains and snows commence and in the early spring before the April rains. Some lines will be found always clean so they can be omitted. Sewers large enough for a man to enter are cleaned with scrapers and shovels, the material being taken up the manholes in buckets and put in wagons to carry away. Sometimes they are "hydraulicked" by pushing a hose through while it is flowing under heavy pressure from a hydrant or fire engine. The process of cleaning a system should commence at the lower end and proceed toward the last lateral. Then the system should be gone over again, This time commencing at the top and working down to clear out all accumulations.

Small pipe sewers are sometimes cleaned by putting in a wooden ball having a diameter a little less than that of the pipe. This ball floats until it meets an obstruction when it is stopped and the water dammed up until enough accumulates to force the obstruction on or wash it out.

Sometimes a scraping is necessary in pipe sewers, especially when there is a heavy confervoid growth. A small wooden float, weighted so it will remain an inch or so beneath the surface, is attached to a string and dropped down an inspection hole or manhole. It floats to the one below where an attendant catches it and then a small rope is tied to the string and hauled through. A heavier rope is attached to this and when the man at the lower end has one end of the rope the scraper is attached to the other end and dragged through. A string is tied to the end of the scraper so the rope can be again hauled through without having to work the float a second time. The scraper should go through twice.

The writer has used as a scraper a heavy chain several feet long. The first three or four feet has steel wire twisted in each link until it resembles a bottle cleaning brush. The long part of the chain dragging behind loosens silt in the bottom. By hauling the

chain down the sewer it helps dam the sewage and the pulling is comparatively light. As the material in the bottom is loosened the extra rush of water helps clean it out. The passage of the scraper is bound to force some material into the house connections. If it goes in the direction of the flow this will not be so serious as if it were dragged against the current. After the scraper goes through a gunny sack filled with hay, excelsior or shavings should be pulled through.

Then the water in all the houses along the line should be turned on to clear out the obstructions in the connections.

When going over the system the second time from the top to the outlet the chain can be inside the sack. If sand deposits in the sewer the scraper should be simply a long heavy chain and it should be hauled through several times, both with and against the current.

There are many sewer cleaning devises now on the market and it will pay to investigate them if any trouble is encountered. Sometimes jointed rods are used and they are very convenient.

In March and April, 1904, the Sanitary Section of the Boston Society of Civil Engineers held a discussion on "The Cleaning and Flushing of Sewers." The full discussion was printed in the October, 1904, number of the Journal of the Association of Engineering Societies. Copies can be procured from the Secretary of the Association, Boston, Mass. The same number contains a paper on "The Disposal of Municipal Refuse." The copy of the Journal referred to costs twenty-five cents and it is worth several times that price for the opinions and experience of the twenty-five eminent engineers who took part in the discussion generally come higher.

SEWER CONNECTIONS.

After a sewer system is constructed, it is a source of considerable expense unless care is taken to regulate connections. Plumbers and drain-layers, if left alone, have a happy-go-lucky way of connecting houses to the sewers in the streets. If properly looked after no harm is done. The following ordinance from Havre, Mont. (prepared by C. W. Swearingen, city engineer), is a good one for towns and cities of less than 10,000 inhabitants. It is simply

a drain-laying ordinance, and does not touch upon matters properly contained in a plumbing ordinance:

An Ordinance to Regulate the Construction, Alteration and Repair of Sewers and House Drains in the City of Havre, Montana.

Be it Ordained by the City Council of the City of Havre, Montana:

Section I—Supervision. The construction, repair and maintenance of all sewers, drains, and cess pools, whether public or private, shall be under the supervision and control of the city engineer.

Section II—License. No person, firm or corporation shall engage in or conduct the business of sewer connecting and house draining, or excavate any trenches for sewer pipe or open, uncover, or in any manner make connection with, or lay any sewer or drain, or attach to, modify or repair any appurtenances to sewer connections with the sewer in the streets or alleys or with any private sewer or drain in the city of Havre without holding the proper license for such work from the City Council of the city of Havre, Mont., excepting only persons operating under special contract with the city for such work.

Section III—Application for License. The application for license shall be presented to the City Council and endorsed by the city engineer; and no person, firm or corporation shall receive such license who does not have an established place of business within the corporate limits of the city of Havre, and who shall not first have furnished the city engineer satisfactory evidence of his or their responsibility and qualifications to ply their trade in acordance with the requirements of this ordinance and the engineer's rules for the conduct of such work.

Section IV—Bond. After favorable action by the City Council granting a license, and before the same shall be issued, the applicant or applicants shall file with the city clerk a bond in the sum of fifteen hundred dollars ($1,500), which bond shall be approved by the mayor and the city attorney, conditioned upon the protection of the city of Havre against all loss or damage which may occur on account of such licensee through any carelessness or negligence in either

the execution or protection of his work, or by reason of any unfaithful or inadequate work done by such person, firm or corporation, or by his or their employes, and that said licensee as such will also conform to the conditions and requirements of the city for his or their government, or in default thereof will submit to such penalties as are or may be prescribed by the city engineer.

Section V—License Fee. The license fee of a drain layer shall be forty dollars ($40.00) per annum, payable in advance, and no license shall be granted for a greater or less period than one year.

Section VI—Use of License. No person, firm or corporation engaged in the business of sewer connecting and drain laying shall allow his or their names to be used by any other person directly or indirectly, either to obtain a permit or to do any work under his or their license or bond.

Section VII—Permit. Before commencing the construction, modification or repair of any sewer, drain or cesspool the drain layer shall first obtain a written permit from the city engineer, and such permit shall be upon the ground at all times during the progress of work and must be shown any officer in authority on demand.

Section VIII—Application for Permit. All applications for permits must be made in writing upon the proper blanks for that purpose, and signed by the owner or his authorized agent, and when it is required they shall be accompanied by a plan showing the whole course of the drain which is to be constructed, together with the size of same, the location of all branches, depth of drain below the floor of building, and such other information as may be required by the engineer for the proper direction of the work. If the drain is to be connected with a sewer built by private parties, or to pass through property not owned by the applicant, the written consent of the owner must be procured and filed with the application before the permit is issued.

Section IX—Fee for Connection. A fee of five dollars ($5.00) will be charged and collected by the city engineer for each connection, to cover the cost of setting grade and filing in the engineer's

office a plan of the work as completed. All moneys collected for sewer connections shall be covered into the city treasury to the credit of the Sewer Maintenance Fund.

Section X—Barricades. Excavations in streets and alleys shall be made in such manner as to impede travel as little as possible, and the engineer may determine and limit the time such excavation may remain open, and when unnecessarily delayed he may direct that the number of workmen be increased to hasten the work to such an extent as he may deem necessary. Red lights shall be maintained upon all unfinished work at night, from dark to sunrise, and sufficient barricades shall be in place at all times until the work is completed.

Section XI—Refilling of Trenches. All trenches shall be refilled in a careful and workmanlike manner, and tamped or puddled so as to replace as nearly as possible all excavated material, and leave the surface in as good condition as before the commencement of work.

Special care shall be observed with trenches within streets and alleys, and all surplus material must be removed when work is completed, and any refilling of trenches necessary to maintain the highway in good condition for a period of one year shall be done by the drain layer.

Section XII—Size of Drains. No drain or sewer pipe shall be less than four (4) inches, internal diameter, and all sewers and drains shall be of sufficient size to accommodate the property they are intended to serve.

Section XIII—Pipe. All pipes shall be first quality, salt glazed, thoroughly vitrified earthenware, sound and well burned, smooth and thoroughly glazed exterior and interior surfaces. All connections shall be laid to a uniform grade. Changes in the direction of the sewer shall be made by bends and suitable fittings. Pipes shall not be cut or chipped except by permission of the inspector, and shall be done under his supervision. Each pipe shall be carefully bedded as laid, the joint filled with fresh mortar composed of one part Portland cement and two parts of clean, sharp sand. The pipe shall be covered with fine earth or sand, free from rocks, and thoroughly packed to prevent the slightest set-

tlement of the drain. A swab shall be drawn through the pipe as laying progresses to clean the mortar joints and exclude objectionable material from entering the sewer. The swab shall be removed from the pipe by the drain layer at the completion of the work of sewer connection. Vitrified pipes shall not approach within two feet of any building, cellar, vault, or areaway, from which point cast iron pipes shall be used. In case soil pipe has been previously laid to said point by the plumber, the drain layer shall connect the two pipes in a careful and workmanlike manner.

Section XIV—Separate Connection. Every building shall be separately and independently connected with the sewer; provided, however, that when, in the opinion of the engineer, it is deemed advisable to connect two or more buildings or a line of tenements with the same sewer, the main drain or lateral shall terminate in a man-hole not less than two and one-half feet in diameter at the bottom and two feet at the top; the inverts shall be carefully formed in the concrete foundation and the top shall have a tight cast iron locking cover.

Section XV—Cess Pools. Cess pools shall not be constructed on property abutting on sanitary sewers, and the use of old cess pools shall be discontinued when public sewers are constructed. Where cess pools are permitted they shall not be located within twenty-five feet of any dwelling, and shall not be less than six (6) feet square and twelve (12) feet deep, lined top and bottom and sides with two-inch plank placed close together, forming a tight chamber with a vent reaching six (6) feet above the surface.

Section XVI—Storm Water. Where rain water leaders are connected with the sewers provision must be made to secure against the entrance of any objectionable material into the sewer.

Section XVII—Improper Use. Entrance into the manholes or opening the same for any purpose whatever except by the engineer or other persons duly authorized, is strictly prohibited. No one shall throw or deposit, or cause or permit to be thrown or deposited in any vessel or receptacle connected with the public sewer, gar-

bage, hair, ashes, fruit, vegetables, peelings, refuse, rags, sticks, cinders, or any other matter or thing whatever, except human excrement, urine, the necessary closet paper, liquid slops, and drainage of such character.

Section XVIII—Inspection. The city engineer may adopt such rules as he may deem necessary to provide for proper inspection of the work, and no work shall be covered until it has been approved by the inspector, who will endorse a certificate of final inspection upon the permit issued for that particular work or connection.

Section XIX—Penalty. Any person, firm or corporation who shall be found guilty of violating any of the provisions of this ordinance, or who shall fail or neglect to comply with any of such provisions, shall, on conviction thereof, be fined not less than five dollars ($5.00) nor more than one hundred dollars ($100.00) for each offense, and ten dollars ($10.00) for each day such person shall continue in violation thereof.

Wilful violation of said regulations or of the directions of the city engineer or his inspector shall be cause for temporary suspension of the license of the offender by the city engineer pending final suspension by the city council, in addition to any other penalties that may be imposed under this ordinance, and such suspension shall operate until such penalties are paid and until license is restored by the City Council; nor shall such suspension give the offending party the right to the return of any money paid for such license.

Section XX—All ordinances and parts of ordinances in conflict with the provisions of this ordinance are hereby repealed.

Section XXI—This ordinance shall take effect and be in force from and after its passage, approval and publication.

Passed by the City Council this 5th day of June, 1905.

Approved by the Mayor this 5th day of June, 1905.

L. NEWMAN, Mayor.

Attest: R. E. HAMMOND,
Acting City Clerk.

SEWAGE DISPOSAL.

It is not enough to have a system of sewers installed and leave the disposal of the sewage to a place outside the city limits, as luck will have it.

It is no longer safe to discharge sewage into rivers and streams, for the population of the country is increasing rapidly, and all streams are used for water supply. A case was decided a few years ago in which a city was enjoined from discharging sewage into the stream from which its own water supply came. The decision was severely commented on by a certain class of people who believe no man should be restrained in doing things to himself.

But people residing along a stream should not be placed in danger because the people higher up desire to save expense. For such the courts give ample protection and the trend of decisions is more and more severe and confining, until it is likely in a few years not the slightest contamination of any water course will be permitted.

Modern sanitary science has shown more diseases to result from impure drinking water than from lack of sewerage facilities and the sources of supply of drinking water must be protected. Seepage through the soil does much to purify the wastes of living. Gases escape into the atmosphere, but are seldom of a harmful nature. The liquids percolating through the soil and removed from beneficial oxygenizing agencies do more harm. If the soil is of a proper kind and the sources of well supply are not too near the surface the liquids may be purified. If they reach underground sheets of water close to wells they may not be diluted enough to be harmless. They may rise through springs into the bottoms of rivers and be rendered innocuous by dilution.

When delivered, however, in quantities into a river near its surface, together with all the waste matter in a putrifying condition, the result is anything but good, and, in fact, in times of sickness, is absolutely dangerous. Cities on the sea coast and on tidal rivers have often been envied because their sewage could be discharged directly into the ocean and be rendered innocuous by dilution. Fish farming and oyster culture, however, are interfered with by such action. The tides bring back wastes the people want to get

rid of and the day is not far distant when all sewage will be purified even before discharging into the ocean and its tidal tributaries.

It costs money to handle large quantities of sewage. This is one of the strong arguments in favor of the separate system of sewerage, which provides a minimum amount of liquid; for storm water is taken care of in other channels.

There are four methods in general use for the disposal of sewage. Briefly described they are as follows, it being remembered that many modifications of each kind exist.

MECHANICAL SEPARATION.

This method separates the solids and fluid matter by straining. The liquid is discharged into a stream or lake comparatively colorless and with slight odor. It is not rendered harmless, however, by this method. Two modern modifications of this oldest of processes are—1st. Irrigation with the effluent. 2nd. Filtration of the effluent.

CHEMICAL PRECIPITATION.

The sewage is run into tanks and chemicals used to precipitate the solids and clarify and purify the effluent.

In both the preceding methods there is a material left, known as "sludge," which is a costly nuisance. Sometimes it is spread over land, allowed to dry and then plowed in. Sometimes it is dried and burned in kilns. Sometimes farmers take it as fertilizer and occasionally makers of fertilizers will take it as a gift. It is almost impossible to sell the stuff and few places can handle it at low cost.

BROAD IRRIGATION.

The sewage is run on land for irrigation. The land is used for raising fruits and vegetables and truck gardening generally. Sometimes land can be rented for the purpose and sometimes it is owned by the municipality and rented to truck gardeners. Properly planned and executed this has, in some places, proven a cheap and efficient method of disposal. But there are many people who object to eating anything grown on a sewage farm. Occasionally such farms have been nuisances.

In combination with septic methods of sewage treatment broad

irrigation will be, and in some places is, successful. It can only be used to advantage, however, where land is comparatively cheap.

FILTRATION.

This is an artificial scientific improvement upon broad irrigation, and is used in connection with mechanical separation, chemical precipitation, sedimentation, septic processes, or alone. As a final treatment for septic sewage, continuous or percolating, filter beds are at present the favorite. Otherwise intermittent filtration is best.

Filter beds may be from two to five or six feet thick, composed of porous material in graded layers. For filtering material there are in use earth, sand, broken stone, burnt clay, pieces of brick, shells, coke, cinders, gravel, glass, etc. The best material is one that will not break down into dust and clog the bed, will be sufficiently porous to have a beneficial straining action and present enough surface to support good colonies of bacteria.

A filter bed works in two ways—1st. It mechanically separates matter in suspension and, 2nd, it contains oxygen in the interstices of the material, which, aided by bacteria, oxidizes organic matter. It should have plenty of air and then the two classes of bacteria mentioned in the chapter on Sanitation can exist. When the filter is clogged only the putrefactive bacteria can exist.

With intermittent filter beds the sewage is retained until the bed is full, when it is drawn off suddenly in order to cause a rush of air into the open spaces. In some systems filling is immediately recommenced. In others the beds are allowed to rest for about one-third the length of time sewage stands in them in order to absorb oxygen

The writer believes that sedimentation and filtration, in combination with irrigation, will be the best solution of the sewage disposal problem. It is not always that the right conditions obtain, however, so the application is comparatively limited. The septic tank then becomes a necessity.

SEPTIC TANK.

On this process the newspaper and magazine scientists have become hysterical. A comparatively recent patented method utilizing

mysterious "bugs" for the protection of man it has been an adjunct of the fairyland of science and entrancing to contemplate. The writer believes that patents on the septic tank process are worthless, as its action has been known many years. Patents on appliances connected therewith to regulate flow, etc., are perfectly safe. Tanks can be, and have been, built without many things often urged upon councils.

Good contact filter beds depend almost wholly upon aerobic bacteria and dispense with putrefactive processes. The septic tank is a tank with, or without, a roof wherein the sewage is held for a time to permit the anaerobic, or putrefying bacteria to throw down the solids and convert them into liquids. There is some precipitation in connection, but no chemicals are used. The action is precisely the same as the action going on in a tight cesspool and privy vault. A small amount of sludge accumulates in the bottom and this sludge can be removed at any time for disposal. It dries into a fine dust and is harmless. It is really an ash such as is left after combustion.

The liquid flows to filter beds where aerobic bacteria complete the work of purification. Where a high degree of purification is desired there should be three sets of filters, but in many plants only one filter is used after the preliminary treatment in the tank.

The real value of the septic tank lies in the fact that it destroys suspended matter without forming any great amount of sludge. It also acts largely to prevent a coating over the bacteria beds of cellulose matter more or less impervious to water. It also forms substances easily acted upon by the nitrifying bacteria.

There is a further advantage, in that in all systems of filtration there comes a time when the filter is clogged to a certain extent and the anaerobic bacteria increase too rapidly while the aerobic bacteria diminish. The beds then become offensive. The septic tank does much to prevent this by furnishing an ideal place for the anaerobes to work.

A septic tank in connection with a filter and subsequent use of the effluent for irrigating kitchen gardens and lawns, is ideal for country residences and houses with grounds.

A complete bacterial purification plant consists of a silt box, or detritus tank, to retain heavy inorganic matter; a septic tank, with pump chamber; a sludge bed, and filter bed, or beds. Although

such a plant will remove 99 per cent of harmful micro-organisms the remainder can do damage, so final treatment over a farm or on sandy soil, is advisable before allowing the effluent to run into a stream used as a source of water supply.

SEDIMENTATION.

Although it was stated at the beginning of the section on sewage disposal that there were four methods of sewage disposal with many variations on each, some readers may think that sedimentation can not properly be treated as a variation. Sedimentation processes required tanks with a very slow velocity in which sludge settled and was periodically cleaned out. It was a process for simplifying the treatment of the liquid sewage. The septic tank really developed from the sedimentation tank.

SEWER ADJUSTMENT SPECIFICATIONS.

It is customary in constructing sewer systems in unimproved streets to have the tops of manholes, catch basins, inlet covers, etc., left flush with the surface of the ground. When the street is afterward paved all these covers are brought flush with the pavement or brought to grade.

For the doing of such work the following supplemental specifications are used in Chicago in connection with street paving contracts:

ADJUSTMENT OF SEWER MANHOLES AND CATCH BASINS.

The contractor shall, for the prices bid per unit, lower, raise and adjust to the proper grade and line all covers to the sewer manholes and catch basins; shall furnish and set new iron covers where needed; shall build new catch basins and shall furnish and lay tile pipe to connect said basins to the sewers.

NEW CATCH BASINS.

All catch basins are to be circular in section and four feet in internal diameter. They are to be built of two rings of brick upon a floor of two-inch pine plank, closely jointed. The bricks in the inner ring (excepting the top and bottom header courses) are to be set vertically. The outer ring may be of bats as far as broken bricks on hand will go, otherwise whole bricks are to be used. The brick work shall be seven feet two inches deep; the top of the brick work shall be two feet in internal diameter, being drawn in by nine header courses, and an iron cover set thereon. The catch basins are to be connected to the sewer with nine-inch tile pipe and trapped with nine-inch half-traps, the bottom of the traps to be set three feet and six inches above the floor of the basins.

The price bid per new catch basin shall include the cost of the catch basin complete including the iron cover and not to exceed sixteen feet of tile pipe.

OLD MANHOLES.

The covers of the manholes shall be taken off and the upper courses of the brickwork removed if they be defective or if it be necessary to set the covers at a lower grade; if it be necessary to raise the covers more than six inches the upper header courses shall be removed until the internal diameter of the brick work shall be two feet and six inches and the manhole shall be built up with new brick work to the proper grade and an iron cover set thereon, using the old cover if it be in a suitable condition.

The price bid per manhole shall include the cost of all the above work and material, including not to exceed two feet of new brick work, excepting the new cover, if furnished.

OLD CATCH BASINS.

The covers of the catch basins shall be taken off and the upper courses of the brickwork removed and the brickwork built up and cover set as specified for old manholes. The catch basins shall be cleaned out, and all open joints filled with fresh mortar. When necessary the new brickwork shall be drawn over to one side so that the cover shall occupy its proper position with reference to the curb. When the catch basin is not located in the line of the gutter a nine-inch inlet pipe shall connect the catch basin with a suitable brick inlet constructed next to the curb.

The price bid per catch basin shall include the cost of all the above work and material, including not to exceed two feet of new brickwork, excepting the new cover and tile pipe, if furnished.

COVERS.

The contractor shall set all covers to the correct grade in a bed of mortar on top of the brickwork above specified. After the foundation for the pavement is laid the covers shall be reset to the exact grade, if necessary, without extra cost.

All new covers shall be of a good grade of cast iron. The curb shall weigh not less than 350 pounds, and the lid, if of iron, shall weigh not less than 120 pounds, provided that if the catch basins are to be built in the parkways lighter covers may be used, weighing not less than 140 pounds. When so directed by the Engineer the contractor shall furnish oak lids for the new covers. The covers and iron lids shall be of the size and form of the iron covers and lids now in use by the Bureau of Sewers in the City of Chicago. The oak lids shall be constructed of two pieces of three-inch oak plank securely fastened to one and one-half inch oak cross pieces with sixteen quarter-inch boat spikes.

The price bid per new cover shall include the cost of the lid and the setting of the cover, and shall be in addition to the price for adjusting the manhole or catch basin.

MASONRY.

The bricks must be clean and thoroughly wet before being laid; the most perfectly formed bricks and those with the smoothest surfaces are to

be used in the inside courses, the smoothest edge of the brick being laid to the face.

No joint shall exceed one-half of an inch in thickness, and all joints on face shall be trowel-struck.

If it be necessary to build more than two feet of brickwork in adjusting the cover of any manhole or catch basin, such excess shall be paid for at the rate of two dollars per lineal foot.

PIPE LAYING.

Each pipe is to be laid on a firm bed, and in perfect conformity with the line and levels given. The ends of the pipes are to abut close against each other in such a manner that there shall be no shoulder or want of uniformity of surface on the interior of the drain. The rings are to be placed centrally around the joints of the pipes. The joints between the rings and the pipes are to be as uniform as possible in thickness and thoroughly filled with mortar. Each joint is to be wiped clean of mortar on the inside before another length of pipe is laid.

The price bid per lineal foot of pipe shall include the cost of all material and labor, including excavation and backfilling, and shall be paid for all inlet pipes and all outlet pipes in excess of sixteen feet for each basin.

MORTAR.

The mortar shall be made by carefully measuring and thoroughly incorporating one part of natural cement with two parts of clean, sharp sand in dry state, and mixed with clean water to the proper consistency, and shall be used while fresh, and the use of mortar which has been set and then retempered will not be allowed. The mortar used in laying pipe sewers shall be of pure cement, mixed and used as above specified, all to be furnished by the contractor without extra charge.

BRICKS.

The bricks shall be of the best quality for the purpose for which they are intended, uniform in quality, sound and hard-burned, free from lime and cracks, and to have a clear, ringing sound when struck, whole and with edges full and square, and of standard dimensions, viz.: 8x4x2¼ inches; they shall be of compact texture, and after being thoroughly dried and immersed in water for twenty-four hours shall not absorb more than fifteen (15) per cent in weight of water.

PIPE.

The pipe shall be straight, smooth and sound, thoroughly burned and vitrified, well glazed, free from lumps or other imperfections, and with the least possible variation from the specified dimension or true cylindrical shape. All straight pipe must be straight in the direction of the axis of the cylinder, and the inner and outer surface of each pipe must be concentric.

BACK-FILLING.

The earth must be carefully replaced around all manholes and catch basins and over all tile pipe laid under this contract in such a manner that no further settlement will take place, and it must be thoroughly rammed with suitable rammers or puddled with water, or both, as the Engineer may direct.

DRAINING INTERSECTING STREETS.

Whenever the grade of the new pavement is such as to interfere with the drainage of intersecting streets into existing catch basins, additional brick inlets shall be built at the outer edges of the new pavement and connected to the catch basins with nine-inch tile. The price bid per lineal foot of tile pipe shall include the cost of this work including the brick inlet.

IRON INLET GRATINGS.

When so directed by the Engineer, the contractor shall furnish and set a cast-iron grating seventeen inches by twenty-four inches, of the form and dimensions shown on the standard plan of sewer manholes and catch basins in the office of the Engineer of the Board of Local Improvements. The grating is to be supported by a cast-iron frame and brick foundation and connected to the catch basin by means of a nine-inch pipe in the manner shown by said drawing.

The price bid per grating shall include the cost of all material and labor above specified, except the tile pipe.

OLD IRON COVERS.

All old iron covers for manholes and catch basins that are not needed on the work shall be delivered by the contractor to the city.

OLD PIPE CONNECTIONS.

The pipe connections from the old catch basins to the sewer shall be examined at the expense of the contractor, and if found defective shall be put in good condition at the expense of the city.

SEWER SPECIFICATIONS.

While the foregoing and following specifications are very complete, it is not advised that they be taken in their entirety for small places, as local considerations must play a large part in all specification writing. The fact that many specifications contain identical or ambiguous clauses seems to indicate that the paste pot and scissors are used more freely than they would be were sufficient thought given to having the specification perfectly clear. Misunderstandings and lawsuits would also be avoided.

SEWER SPECIFICATIONS—CITY OF CHICAGO—1905.

INSTRUCTIONS TO BIDDERS.

The contract of which these specifications are a part is drawn under an ordinance which was heretofore passed by the City Council of the City of Chicago, providing for the said improvement, and it is understood that the contractor shall carefully examine the said ordinance, as under the laws of

the State of Illinois the improvement as completed must comply with the terms and provisions of the ordinance providing for the said improvement.

It is the intention of these specifications to provide for this improvement in a complete, thorough and workmanlike manner. The contractor to whom the work is awarded, shall furnish all materials, labor and appurtenances necessary to complete the work in accordance with these specifications, and anything omitted herein that may be reasonably interpreted as necessary to such completion is to be merged in the prices bid for the improvement.

No bid will be accepted which does not contain an adequate or reasonable price for each and every item named in the schedule of quantities.

Bidders must satisfy themselves by personal examination of the location of the proposed work, and by such other means as they may prefer, as to the accuracy of the estimate of quantities.

Bidders must present satisfactory evidence to the Board of Local Improvements that they have been regularly engaged in the business of building sewers, or are reasonably familiar therewith, and that they are fully prepared with the necessary capital, materials and machinery to do the proposed work.

All bids must be made subject to the rights of the owners of a majority of the frontage, to contract for the improvement as provided for in Sections 80 and 81 of an Act of the General Assembly of the State of Illinois, entitled "An Act Concerning Local Improvements," approved June 14, 1897, in force July 1, 1897, and the amendments thereto.

No bids will be accepted from any person or firms who may be in arrears to the City of Chicago upon debt or contract, or who may be in default, as surety or otherwise, upon any obligation to said City of Chicago or behind specified time on any previous work. Companies or firms bidding for the work herein described, must state in the proposal the individual names and places of residence of the officers or persons comprising such company or firm.

The Board of Local Improvements expressly reserves the right to reject any or all bids, or to accept bids separately as to different sections of the work, or to accept any bid in the aggregate.

A list of the sewers to be constructed is given in the form of proposal, "Letting No....................," and the proposal, with all information, special notation, etc., shall be considered a part of these specifications.

The plans and drawings showing location and dimensions of sewers to be constructed, prepared by the Board of Local Improvements of the City of Chicago, and on file in its office, with all notes, dimensions, figures and corrections thereon, shall be considered a part of these specifications, and in event of any discrepancy between plans and specifications, the judgment of the Board of Local Improvements or its authorized agent shall be decisive thereon.

NATURE OF THE WORK.

The contractor shall, for the contract price per lineal foot for the sewer proper, furnish all the material and all tools and do all the work prescribed in these specifications, and shown on the plans attached, including foundation and all necessary work and material for building of outfall, shall make the requisite excavation for building the sewer, and its appertaining structures and connections, shall do all the ditching, diking, pumping, bailing and drain-

ing, all sheeting and shoring; shall make all provisions necessary to maintain and protect all buildings, walls, fences, trees, gas pipe, water pipe, conduits, sewers and other structures of whatever nature; shall provide all bridges, fences or other means of maintaining travel on intersecting streets, and on streets or roads in which the trenches are excavated; shall maintain the same in good and safe condition so long as may be necessary; and then shall remove such temporary expedients and restore such ways to their proper condition; shall provide watchmen, fences, red lights and all other precautionary measures necessary to the protection of person and property; shall provide all centers and forms; shall construct all foundations, all brick, tile pipe, concrete, stone and timber work; shall set in place all iron work, and refill all trenches; and shall put in complete working order the sewer or sewers awarded him, and shall do each and all to the satisfaction of the Board of Local Improvements. The contract price is to include the cost of the removal of trees, roots, timber or masonry structures or other obstacles, and the delay or damage occasioned by same, whether any of these obstacles are shown on the plan or not.

EXCAVATION.

The ground shall be excavated in open trenches, except where tunneling is considered necessary or proper by the Engineer, in such direction as is required, to the width and depth as may be necessary for the proper construction of sewer according to plan.

The trenches must be of sufficient width to admit of ample room within the lines of the sheeting to permit of the work being constructed in the manner and size specified. Wherever the nature of the ground will admit of it the bottom of the excavation is to have the shape and dimensions of the outside of the lower half of the sewer. In order to secure this the contractor is to provide a pattern or form made with two segments, one to fit the outside and the other the inside of the invert. It is to be firmly and securely set to the proper grade, as given by the Engineer, and is to remain unmoved in its position until after the masonry is laid. The bed for the sewers is then to be brought to the required shape, by trimming, with suitable tools, to a line stretched from the outside of the masonry to the form.

If the character of the ground met with in excavating is such that the external form of the sewer can not be preserved, the excavation shall be made to conform as nearly as possible to the external shape and dimensions of the sewer, and the space between the external sewer lines and the bottom and sides of the excavation as made, shall be filled with dry earth by the contractor.

Where streets are paved all surplus material excavated must be removed from the trench and the streets as fast as excavated by the contractor at his own expense. The sidewalks must in no case be obstructed, and the contractor shall make provisions at all cross streets for the free passage of vehicles and foot passengers, either by bridging or otherwise.

The excavation of the trench shall not advance more than 600 feet ahead of the completed masonry or pipe work, except where, in the opinion of the Engineer, it is necessary to drain wet ground.

Where rock is encountered in excavating the trenches, it is to be removed by drilling and blasting, or otherwise, to the level of the outside

of the bottom of the sewer. Whenever a water main, gas pipe or other conduit crosses the line of the trench, the rock on each side of the pipe, for the distance of two feet, is to be removed without blasting. Where blasts are made the trench is to be carefully covered with suitable brush or timber or matting to prevent danger to life and property, and the contractor must secure a special permit for blasting. Before the sewer is built all irregularities of the rock are to be filled with sand and gravel, well rammed into its place, without extra compensation.

For all rock excavation. in addition to his price per foot of sewer, the contractor is to receive a compensation of three dollars per cubic yard. In estimating the number of cubic yards, the necessary width of the trench at the surface of the rock, by the depth from the surface of the rock to the bottom of the invert of the sewer, is to be considered the dimensions of the rectangular section upon which estimates of quantities are to be based, no allowance being made for excavation beyond these boundaries and no deduction made for the portion which comes on the quarters of the invert that may not be removed. Boulders, one-quarter cubic yard and over in size, will be measured as rock excavation. Hardpan and boulder clay shall not be classed as rock, although it may be more economical to remove the same by blasting.

No claim for an amount of money beyond the contract price of the work will be entertained or allowed on account of the character of the ground in which the trench or other excavations are made, except for the rock cutting heretofore specified.

The contractor must assume the risk of meeting quicksand, hardpan, boulder clay, rubbish, unforeseen obstacles, underground conduits, railroad tracks, pavements, etc.

All water, gas, or other kinds of pipes or conduits are to be carefully supported and protected from injury by the contractor, either until the sewer is built and the backfilling finished, or, if it is necessary, until the proper person shall remove or change them. Nothing in this contract shall be so construed as to relieve any person or corporation, owning or using any pipes, conduits or tracks from the obligation to maintain and protect such pipes, conduits and tracks without any expense to the City of Chicago or to the contractor building said sewer.

When existing sewers have to be taken up or removed, the contractor must provide and maintain temporary outlets and connections for all private or public drains, sewers, or catchbasins, and he must take care of all sewage and storm water which will be received from these drains and sewers, and discharge the same; and for this purpose he must provide and maintain at his own expense an efficient pumping plant and temporary outlet, and be prepared at all times to dispose of the water and sewage received from these temporary connections until such times as the permanent connections with the new sewers are built and in service, which permanent connections shall be made by the contractor in a careful and workmanlike manner.

All paving, graveling, macadamizing, planking, sidewalks, culverts, and crosswalks, or any street paving or walk whatever, are to be carefully removed before the excavation is made, and kept separate from other excavated material, and carefully replaced after sewer is completed.

Tunnels shall be of such width and height as the Engineer may direct, and shall be excavated in conformity with the cross-section to be furnished by him.

SHEETING AND BRACING.

To secure the protection of the work, the streets adjacent, buildings, or other improvements, the contractor must furnish and put in place at his own expense such shores, braces, sheeting, etc., as may be necessary for the safety of the work or the public.

The sheeting and bracing shall be removed as the work progresses, in such manner as to prevent the caving in of the sides of the excavation, or any damage to the masonry.

The Board of Local Improvements may order the sheeting and bracing left in, when in its opinion it is necessary for the protection of the work; in such cases only will a charge be allowed for the same at the rate of $18.00 per thousand feet B. M.

The contractor shall at his own expense shore up and restore, and make good, as may be necessary, all fences, buildings, walls, conduits, or other properties which may be disturbed during the progress of the work, and the said contractor will be held responsible for all damages which may happen to neighboring properties, or in any other way from neglect of this precaution.

The price paid per lineal foot of sewer shall include the cost of all excavations, all temporary supports and braces that may be necessary to secure a safe prosecution of the work until the permanent structure is complete; such temporary supports must in all cases be removed by the said contractor at his own expense after or concurrently with the completion of the permanent structure.

FOUNDATIONS.

Whenever the ground is sufficiently firm and unyielding, the masonry or pipes are to be laid directly on the bottom of the excavation; but whenever this shall not be the case and such foundation is not shown on the plan, it shall be built of masonry, concrete, or of plank and timber, as the Board of Local Improvements may direct.

The contractor will be allowed extra compensation for this work at prices named below for the different kinds of foundations required.

The following are the prices to be paid for foundations, timbering, sheeting, etc.:

$18.00 per 1,000′ B. M. for plank and sheeting.

$ 8.00 per cubic yard for brick masonry.

$ 7.00 per cubic yard for concrete.

PROTECTION AGAINST WATER.

The contractor shall do all pumping and bailing, build all drains, and do all other work necessary to keep the trench and sewer clear of ground water, sewage, or storm water during the progress of the work, and until the cement mortar is sufficiently set to be safe from injury. To this end in wet trenches he shall keep a channel open on each side of the work during its construction, which shall be maintained so as to catch the water

from the sides of the trench and to conduct it to a sufficient sump or bale hole in front of the work.

BACKFILLING.

After the arching is completed on any length of sewer, and before the centers are struck, the trench is to be filled to a height of not less than one foot above the arch. On brick sewers the spandrels are to be well consolidated by thorough ramming wherever the ground is of a nature to admit it. As soon as the mortar and masonry are sufficiently set, the trench is to be sufficiently filled to prevent liability ot injury to the banks, road surfaces, adjacent pipes, railroad tracks, sidewalks, or other property, public or private.

The surplus material taken from the trench is to be removed entirely from the street, or disposed of in such a manner as directed, so as to save the city from all damages or expense on account thereof.

The backfilling shall in all cases be left with a smooth and even surface and a sufficient crown. Where required the backfilling shall not be left unfinished more than 600 feet behind the completed masonry or pipe work.

Ditches shall be opened and connected to the inlets of the catchbasins, hereinafter provided for, so as to provide for the adequate drainage of the surface of the adjacent lands and ditches.

FILLING.

The sewers shall in all cases be covered with earth to a depth of not less than three feet, and where the trenches do not furnish sufficient material the contractor shall supply such deficiency at his own expense.

When additional filling is required to be placed over the sewer for its protection, the contractor shall furnish and spread earth, cinders or clean ashes, free from animal or vegetable matter, in such a manner and in sufficient quantity, so that after it is thoroughly compacted the embankment shall be of uniform grade and cross-section, and of the dimensions shown or specified in the plans or proposal sheet. The number of cubic yards stated in the proposal sheet is approximate only.

RESTORATION OF SURFACE OF STREET.

In all streets or parts of streets that are paved, graveled or macadamized, all the backfilling is to be well rammed with suitable tools in layers not exceeding twelve inches in depth, provided the ground is clay, stiff loam, or of a tenacious nature. If the ground is sand or gravel, the backfilling is to be puddled in such a manner as directed. After being puddled or rammed to the required height, the pavement shall be relaid carefully and thoroughly in a manner adapted to its peculiar character, and to the satisfaction of the Engineer.

When the work is completed all surplus material, earth, rubbish, etc., must be removed and the surface of the streets included in this contract must be left in as good condition, in all respects, as it was before the commencement of the work, and it must be maintained in such condition during a period of one year after acceptance of the work.

CENTERS AND PATTERNS.

The centers, patterns and templets necessary in the construction of the work are to be furnished by the contractor at his own expense.

The centers upon which the arch is formed must be strong and accurately made, and shall in no case be used until approved by the Engineer, and when in his opinion either the templets or centers become unfit for use they shall be removed from the work and new ones supplied by the contractor; on curves they must correspond to the radius of the curve.

MASONRY.

Unless otherwise noted on the proposal sheet, all brick sewers, the internal diameters of which are 2½ feet or less, shall be built of one ring of brick; all brick sewers, the internal diameter of which exceed 2½ feet and not more than 6 feet, shall be built of two rings of brick; all brick sewers, the internal diameters of which exceed 6 feet, and are not more than 10 feet, shall be built of three rings of brick; and all brick sewers, the internal diameters of which exceed 10 feet and are not more than 15 feet, shall be built of four rings of brick.

The most perfectly formed bricks and those with the smoothest surfaces are to be used in the inside of the sewer, the smoothest edge of the brick being laid to the face. The courses are to be laid in line and kept perfectly straight in the direction of the sewer and parallel to the rise of the same, and shall be laid as stretchers, breaking joints with those in the adjacent courses. Every brick must be laid separately in full mortar joints on bottom, side and end. No joint shall exceed one-half (½) of an inch in thickness, and all joints on face shall be trowel-struck. The mortar joints on the inside of the sewers, below the center line, are to be carefully struck when laid, and those above to be scraped smooth with the bricks immediately after the centers are struck. The refuse mortar to be scraped off and removed entirely from the sewer before it has time to harden.

All inverts or bottom courses are to be laid to line from templets, accurately made, and correctly set to the lines and grades furnished.

No work in masonry shall be done when the thermometer is below twenty-five (25) degrees F., without permission from the Engineer, and then under conditions for protecting it from frost, approved by him.

MANHOLES.

All manholes are to be circular in section and three feet internal diameter. They are to be built with two rings of brick, giving a thickness of eight inches to the wall. The bricks in the inside ring are to be set vertically. The outer ring may be built of bats as far as broken bricks on hand will go, otherwise whole bricks are to be used.

On sewers three feet in diameter and greater the manholes shall be supported by the arch invert of the sewer without additional foundation. On sewers less than three feet in diameter the invert of the sewer through the manholes shall be built of two rings of brick and on each side thereof shall be built a solid brick foundation twelve inches thick, making the entire foundation four feet and six inches in diameter.

The top of the manhole is to be two feet in diameter, being drawn in by means of six header courses the diameter being decreased two inches for each course, and an iron cover set thereon. On unpaved streets, the tops of the covers of the manholes are to be at the surface of the streets; on paved streets, one-half inch lower.

The cost of all manholes shall be included in the price paid per lineal foot of sewer.

CATCH-BASINS.

All catch-basins are to be circular in section and four feet in internal diameter. They are to be built of two rings of brick upon a floor of two-inch pine plank closely jointed. The bricks in the inner ring (excepting the top and bottom header courses) are to be set vertically. The outer ring may be built of bats as far as broken bricks on hand will go, otherwise whole bricks are to be used. The brick work shall be seven feet two inches deep; the top of the catch-basin shall be two feet in diameter, being drawn in by means of eight header courses, the diameter being decreased three inches for each course, a top header course, being laid flush with the course below and an iron cover set thereon.

The catch-basins are to be connected to the sewer with nine-inch pipe and trapped with nine-inch half-traps, the bottom of the traps to be set three feet and six inches above the floor of the basin.

The top of the cover shall be set at the grade given by the Engineer; and when so directed the contractor shall set a piece of nine-inch pipe in the side of the basin at the proper elevation to receive the water from the adjacent ditches.

The cost of all catch-basins shall be included in the price paid per lineal foot of sewer.

COVERS.

All covers used shall be of good quality of cast iron, the curb shall weigh not less than 350 pounds and the lid shall weigh not less than 120 pounds, and shall be of the same size and pattern as iron covers now in use by the Bureau of Sewers, in the City of Chicago, provided that if the catch-basins are built in the parkways, lighter covers may be used weighing not less than 140 pounds.

PIPE LAYING.

Each pipe is to be laid on a firm bed, and in perfect conformity with the line and levels given by the Engineer. The ends of the pipes are to abut close against each other in such a manner that there shall be no shoulder or want of uniformity of surface on the interior of the drain. The joints are to be as uniform as possible in thickness and thoroughly filled with mortar; where the pipe is laid in running sand the joints must be caulked with oakum. Each joint is to be wiped clean of mortar on the inside before another length of pipe is laid.

JUNCTION OF SEWERS.

The junction of two or more sewers must be made in strict conformity with the plans. The work must be done with special care and in a perfect manner and the brick at the joining edges must be shaped smoothly to proper curves and the two sewers joined with a thorough bond, the cost of all junctions to be included in the price per lineal foot of the main sewer.

When connections are made with sewers carrying water, special care must be taken that no part of the work is built under water; a flume or dam must be put in and the new work kept dry until finished.

SIDE JUNCTIONS.

Intersections or lateral sewers, whether of brick or pipe, and all junctions for catch-basin drains are to be built into the sewers at such places as are shown on plans. Six-inch junctions for house drains to commence ten feet from street corners and to be placed thence twenty-five feet apart through the blocks, or as otherwise shown on the plans, shall be built into the sewers in a thorough and workmanlike manner. Whenever required the brick intersections are to be strengthened by backing up the angles with piers of masonry. The junctions are to be bricked off at the ends, thoroughly closing them. The pipe junctions are to be closed by laying the brick against the end of the pipe. In no case are the bricks to be placed inside the pipe. All dead ends of the sewers are to be closed with eight inches of brick work.

OUTLETS.

The outlets for main sewers are to be built in accordance with plans and specifications supplied for each case. The terminations or intersections of sub-mains and laterals with main and sub-mains respectively, are to be made through brick or pipe junctions previously built. If for any cause the junction previously made in the sewer, with which the contractor is to connect, is to be changed in size or position, or a new one is to be built, the contractor shall, without extra price, do all the necessary labor of any kind, growing out of said change.

MATERIALS.

All materials, of whatever nature, required in the construction of the sewers, catch-basins and manholes, shall be new and of the best quality, and shall be furnished by the contractor.

BRICKS.

The bricks shall be the best quality for the purpose for which they are intended, uniform in quality, sound and hard burned, free from lime and cracks, and to have a clear ringing sound when struck, whole and with edges full and square, and of standard dimensions; they shall be of compact texture, and after being thoroughly dried and immersed in water for twenty-four hours shall not absorb more than 15 per cent in weight of water.

PIPE.

The pipe shall be straight, smooth and sound, thoroughly burned, well glazed, free from lumps or other imperfections, and with the least possible variation from the specified dimensions or true cylindrical shape. All straight pipe must be straight in the direction of the axis of the cylinder, with the ends cut at right angles with the axis of the pipe and the inner and outer surfaces of each pipe must be concentric. The thickness of the pipe shall be: For 18-inch pipe, 1¼ inches; for 15-inch pipe, 1⅛ inches; for 12-inch pipe, 1 inch; and for 9-inch pipe, ⅞ inch, with a limit of variations not exceeding ⅛ of an inch either way. When double strength pipe is specified, the standard of thickness shall be one-twelfth of the internal diameter of the pipe. The curves, slants and Y junctions must conform to all the foregoing requirements as regards quality, form and workmanship, and the thickness shall be equal to that of pipes of the same caliber into which the Y may be

jointed. All slant junctions and branch junctions shall be molded for an angle of thirty-four degrees with the sewer with which they are to connect.

CEMENT.

The cement shall be fresh made, of some satisfactory and reliable brand, and of such quality and uniformity as has been demonstrated by the Board of Local Improvements of Chicago to be of superior quality and thoroughly adapted to the construction of sewers and similar work, and shall be approved by the Engineer.

Natural cement shall be so finely ground that 90 per cent of the whole will pass through a sieve of 100 meshes to the lineal inch, and when treated in the usual manner for tensile strength, shall give results comparing favorably with the best brands of American Natural Cement. The cement, when tested in the usual manner, shall take an initial set in not less than 10 minutes.

Portland cement shall be of some brand of reputation known and established by use. It shall be ground so that ninety-two (92) per cent will pass through a standard sieve of 100 meshes to the lineal inch, and when mixed, one part cement and three parts sand, shall show a tensile strength of two hundred pounds per square inch in seven days—one day in air and six days in water—and an increase of not less than 20 per cent in strength at the end of twenty-eight days, and an additional increase of 15 per cent at the end of three months.

As ample time is required for making tests, the contractor shall submit samples of the cement he desires to use and one or more brands may be approved by the Engineer, any of which the contractor may use.

If large quantities of Portland cement are to be used in this work the contractor shall deposit and store the cement in a suitable warehouse, where it shall remain under the supervision of the Board of Local Improvements until after it has been tested and accepted by the Engineer.

MORTAR.

The mortar for brick work shall be made by carefully measuring and thoroughly incorporating one part of natural cement with two parts of clean, sharp sand in dry state, mixed with clean water to the proper consistency, and shall be used while fresh, and the use of mortar which has set and then been retempered will not be allowed. The mortar used in laying pipe sewers shall consist one part of natural cement and one part of clean sand mixed and used as above specified, all to be furnished by the contractor without extra charge.

CONCRETE.

All concrete shall be composed of one part Portland cement, three parts clean torpedo sand and six parts of broken stone. The stone shall be of good quality, graduated in size, angular in shape and free from dirt or clay. All stone must be broken, so as to pass through a ring one and one-half inches in diameter. The cement and sand shall be measured and shall be thoroughly mixed dry, until the mixture is of a uniform color, and shall be wet with as little water as will render it proper for use, and thoroughly worked. The stone shall be added and the whole shall be mixed until

each stone is thoroughly coated with mortar. The stone shall be wet or washed, if required, before it is added to the mortar.

INSPECTION OF WORK AND MATERIALS.

All materials, of whatever nature, shall be inspected upon the ground when delivered, by an inspector appointed by the Board of Local Improvements, who shall, upon finding defective or poor material of any kind, mmediately report the same to the Engineer in charge of work, and the contractor shall, when notified by said Engineer or inspector, at once remove said defective or poor material from the line of the work.

Inspectors will be appointed whose duty it shall be to report to their superiors any neglect or disregard of these specifications by the contractor; but the right of final acceptance or condemnation of the work will not be waived thereby, nor by any other act of the City of Chicago by its officers or agents relating thereto.

If at any time during the progress of the work any rejected or inferior materials should be found in the street, or any portion of the work should be improperly done, such material and work shall be removed and replaced by proper material and work at the expense of the contractor. Notice of any imperfections in the work or material to any foreman or agent in charge of any portion of the work in the absence of the contractor shall be considered as notice to the contractor.

The contractor shall execute the work only in the presence of the Engineer or Inspector during the usual working hours of the day, unless otherwise directed by the Engineer; but the presence or superintendence of the said Engineer or Inspector shall in no way relieve the contractor of the responsibility of his work, or be any warrant for him to furnish bad material or poor workmanship.

The contractor shall notify the Engineer 48 hours before beginning work on this contract of his intention to do so, and in case of a temporary suspension of the work, he shall give a similar notice before resuming work.

The contractor will be required to dig all stake holes necessary to give the lines and levels for the work in time for the daily visit of the Engineer in charge at such time as he may appoint, and shall furnish and drive all stakes as directed.

The contractor shall furnish all necessary facilities, should it be deemed advisable by the Board of Local Improvements to make an examination of any work already completed. If the work is found defective in any respect the contractor shall defray the expense of such examination and of satisfactory reconstruction. If the work is perfect, such expense will be allowed for.

All the work shall be executed in the best and most workmanlike manner and no improper material shall be used, but all materials of every kind shall fully answer the specifications, or if not particularly specified, shall be suitable for the place where used and satisfactory to the Board of Local Improvements.

Whenever the word "Engineer" is used, it is understood to mean the Board of Local Improvements, any member of the Board, the Engineer of the Board, or in his absence his duly appointed assistant or inspector representing him, limited to the special duties imposed on each.

EXTRA WORK.

The actual length of each sewer to be built may be more or less than the corresponding length given in the proposal sheet or plan, but no variation will be made in the rates on that account. No extra or customary measurement of any kind will be allowed in measuring the work under these specifications; but the actual length, area, solid contents or number shall be considered and the length shall be measured on the center line of the work whether straight or curved. The contractor will be paid the contract price for each unit of work done, which price will include the cost of all work herein described, including all junctions, manholes and catchbasins, with their connections.

No claim whatever will be allowed the contractor for extra work or material, or for a greater amount of money than is herein stipulated to be paid, unless some change in or addition to said work, requiring additional outlay by the contractor, shall first have been ordered, in writing by the Board of Local Improvements, said writing to be attached to the contract for the making of said improvement, and stating that such work is not included in the contract, what the extras are, and that such are necessary for the proper completion of the work, or for the security of the work previously done, and the reason therefor.

The Board of Local Improvements reserves the right to make any change in the plans and specifications that it may deem desirable or necessary, which change may increase or diminish the quantity of material or labor or the expense, and such change shall not violate or annul the contract or agreement hereby entered into, but the contractor shall furnish the necessary labor and material to complete the contract as amended. The value of the work so added or omitted shall be added to or deducted from the contract price as the case may be, and the determination of such value shall be based on the rates and prices named in this contract, when such rates and prices can be equitably applied, otherwise the value shall be determined by mutual agreement between the Board of Local Improvements and the contractor.

If, for any cause, the Board of Local Improvements finds it necessary or desirable to suspend operations for any considerable length of time, it is to be done by the contractor on due notification, and he will not be entitled to any damages of any kind or nature whatsoever because of such detention. He will, however, be allowed further time in the completion of his contract, equal to the delay caused by the suspension of the work.

All loss or damage arising out of the nature of the work to be done, or from any detention or other unforeseen or unusual obstruction or difficulty, which may be encountered in the prosecution of the work, or from the action of the elements, shall be sustained by the contractor.

GUARANTEE.

It is understood and agreed that all labor and material shall be of such character that the entire work, including the restoration of the surface of the street, shall be and remain in good condition during the entire period of one year from the acceptance of the work, and the coutractor hereby agrees to keep in perfect repair, during such period, the whole of his work, except in

cases where the repairs may be rendered necessary by causes clearly beyond his control.

In the event that any pavement, sidewalk, crossing or other surface which may have been disturbed in the prosecution of the work shall not be restored by the contractor within a reasonable time after the completion of the work and the acceptance of the same by the Board of Local Improvements, or if any such pavement, sidewalk, crossing or surface shall, because of the settlement of the back-filling, be in bad condition during the period of the year after the acceptance of the work, or if any of the contractor's work shall be found defective or incomplete during such period, and the contractor shall neglect to repair such defective work within 15 days from the date of a notice from the Board of Local Improvements directing him to make such repairs, then the City of Chicago may make such repairs and restoration of the street at the expense of the contractor and shall deduct the cost thereof from any money belonging to the contractor in the control of the City.

STREET PERMIT.

Before beginning work on this contract, the contractor shall obtain from the proper officer a street opening permit and shall deposit with the Commissioner of Public Works a sum of money sufficient to pay for the cost of any repairs or restoration of the surface of the street for which the contractor shall be liable under the terms of this contract. At the expiration of one year after the completion of the work and the acceptance of the same by the City, the money so deposited, or any balance thereof, shall be returned to the contractor, all charges against and deductions from such deposit being made in accordance with the terms of this contract.

DIRECTION AND SUPERINTENDENCE.

(NOTE—See street specifications for Chicago.)

CONTRACTOR'S DEFAULT.

(NOTE—See street specifications for Chicago.)

LABOR CLAIMS.

In accordance with an ordinance passed by the City Council March 10, 1879, the Board of Local Improvements reserves the right to refuse to issue a voucher and to direct that no payment shall be made to the contractor in case it has reason to believe that the said contractor has neglected or failed to pay any sub-contractor, workman or employe for work performed on or about any of the sewers included in these specifications, until said Board is satisfied that such sub-contractor, workman or employe has been fully paid.

After full completion of the work to the satisfaction of the Board of Local Improvements, it reserves the right, in accordance with said ordinance of the City Council, to refuse the payment of 15 per cent reserve, or any amount due said contractor, until it is satisfied that all sub-contractors, workmen and employes of said contractor have been fully paid.

The Board also reserves the right after ten days' notification to said contractor, in accordance with the provisions of said ordinance, to apply all money due, or that may become due under the contract for sewers included

in these specifications, to the payment of such sub-contractors, workmen or employes of said contractor, without other or further notice to him of its intentions so to do.

The failure of the Board of Local Improvements to comply with the provisions of the ordinance in regard to unpaid sub-contractors, workmen or employes, shall in no wise affect the liability of the contractor or his sureties, to the city or to the persons who are or who may have been in his employ.

MANNER OF PAYMENT.

(NOTE—See street specifications for Chicago.)

CONTRACTS PAYABLE FROM SPECIAL ASSESSMENT ONLY.

(NOTE—See street specifications for Chicago.)

TIME FOR COMPLETION OF WORK.

The work to be performed under these specifications shall be commenced within fifteen (15) days after the time of signing the contract for same, and shall be completed on or before.................................... and the said time specified for completion of the work is an essential condition of this contract. Provided, however, that if the contractor is delayed by the city in the commencement of the work, or in case the work is suspended by order of the city authorities, then the time of such delay or suspension shall be added to the time for the completion of this contract.

After the date specified for the completion of this contract, the Superintendent of Sewers shall have the right to issue permits to any person to make connections with the sewer herein provided for, although the work may not have been fully completed and accepted, and the issuance of any such permits shall not entitle the contractor to any additional allowance or relieve him from any responsibility.

ASSIGNMENT PROHIBITED.

No part of the work herein specified shall be assigned or sub-contracted without the written consent of the Board of Local Improvements, and in no case shall such consent relieve the contractor from the obligations herein entered into by him, or change the terms of this agreement.

LIABILITY OF CONTRACTOR IN THE MATTER OF BARRIERS AND DAMAGE TO PERSONS OR PROPERTY.

If, in the prosecution of said work, it shall be necessary to dig up, use or occupy any street, alley, highway or public grounds of said city, the contractor shall erect and maintain such strong and suitable barriers, and also during the night time such lights, as will effectually prevent the happening of any accident or harm to life, limb or property, in the consequence of such digging up, use or occupancy of said street, alley, highway or public grounds, and the contractor shall be liable for all damages of every kind and nature occasioned by reason of his failure to comply with any of the provisions mentioned in this paragraph. Said contractor shall also be liable for any damage to persons or property occasioned by the negligence of such contractor, his agents, employes, workmen or assignees.

USE OF VACANT LOTS

The contractor will not be allowed to occupy or use any vacant lot as a depository for stone, sand, gravel or other material, without written permission of the owner or agent of the land, a copy of which shall be filed with the Board of Local Improvements.

RAILROADS.

All railroads not required to be taken up must be kept in running order where practicable. No allowance will be made for delays or other damages occasioned by the necessity of keeping the railroads in constant running order, or for removing or replacing the same when it is necessary to do so.

EMPLOYES.

The contractor shall employ capable superintendents or foremen to represent him on the work, and they shall receive and obey orders from the Engineer.

The Board of Local Improvements shall have authority to order the dismissal of any employe on the work who refuses or neglects to obey any of its instructions relating to the carrying out of the provisions and intent of these specifications, or who is incompetent, unfaithful, abusive, threatening or disorderly in his conduct, and such person shall not be again employed on the work.

PATENTS.

(NOTE—See street specifications for Chicago.)

USE OF FIRE HYDRANTS.

(NOTE—See street specifications for Chicago.)

SWORN STATEMENT REQUIRED.

(NOTE—See street specifications, Chicago.)

ACCEPTANCE OR REJECTION OF BIDS.

All bids will be made subject to the rights of the owners of a majority of the frontage to contract for said work, as provided for in Section 80 of an Act of the General Assembly, approved June 14, 1897, and in force July 1, 1897, and the amendments thereto, and upon the express condition that when a bid is accepted by the City of Chicago and the owners of a majority of the frontage fail or neglect to avail themselves of the provisions of said Section 80, if such original bidder fails or refuses for fifteen days after the first posting or publication of the notice award, or in case a contract be made by the owners, and default by them, then, within ten days after notice that such owners are in default, to enter into a contract, then the certified check deposited with the Board of Local Improvements with such bid shall be thereby forfeited to the City of Chicago.

No bids will be accepted from any persons or firms who may be in arrears to the City of Chicago upon debt or contract, or who may be in default as surety or otherwise, upon any obligation to said city, or behind specified time on any previous work. Companies or firms bidding for the work herein described must state in the proposals the individual names and places of residence of the persons comprising such company or firm.

The Board of Local Improvements expressly reserves the right to reject

any or all bids, or to accept bids separately as to any part of the work, or to accept any bid in the aggregate.

The undersigned hereby certifies that he has read the foregoing specifications, and that his proposal for the work is based on the conditions and requirements embodied therein, and should the contract be awarded to him he agrees to execute the work in strict accordance herewith.

Name ....
Residence ....
Name ....
Residence ....
Name ....
Residence ....

PIPE SEWERS.

A good specification for laying pipe sewers from *Engineering News:*

Only one man under each inspector shall be allowed to lay tiles on the main sewer, and only one on house connections; and no tile shall be laid except in the presence and according to the directions of the Inspector.

Tile pipes shall be so laid as to be evenly supported throughout the whole length of the barrel, with no weight resting on the bell. If the trench is dug deeper than the grade of the barrel no spalls, shims or lumps shall be used to raise the pipe to grade, but an even bed shall be formed of sand or approved fine material properly tamped.

Joints shall be made as follows: (1) Line with mortar the lower third of the entire circumference of the bell; (2) insert the pipe to be laid and a jute gasket freshly dipped in neat grout; (3) bring the pipe to grade and line; (4) caulk the gasket tightly into the joint; (5) fill the joint with mortar mixed rather stiff, using a rubber mitten; (6) tamp mortar into joint with an approved tool until it is solidly filled; (7) smooth on mortar, using a rubber mitten, until its surface makes a bevel of not more than 60 degrees with the pipe; (8) protect the cement (preferably with burlap), and fill around the barrel of pipe with sand or similar material, tamping solid with an approved tool; (9) remove burlap and cover joint and pipe with fine material; (10) clean out and point joint on inside of pipe.

On pipes less than 12 inches in diameter cleaning out may be done with a bag, stuffed so as to tightly fill the tile, drawn through each length of tile as it is laid. All pipes must have the lower third of the joint completely filled with cement; pipes larger than 18 inches shall have the lower half pointed, and larger than 24 inches the whole of the joint, using neat cement on the top half if necessary.

(NOTE.—The writer fails to see the necessity for specifying a gasket in sewer pipe joints except when the sewer is laid in water or in running water. In such case mud might get in or the cement be washed out of the joint. The gasket should be dipped in neat cement grout. When the trench is dry and it is reasonably

certain the mortar can set before any water can get in through the joints he prefers to have the joints filled with a stiff mortar. All sewer pipe should have extra wide and deep sockets no matter whether it is double or ordinary strength shell.).

LUMBER LEFT IN TRENCHES.

In small places it is not customary to leave lumber in trenches. The writer has had inquiries as to why it is done.

If the ground has any tendency to slide, the filling in the trenches will settle too slowly to oppose any force to the squeezing in of the banks. When there are water pipes or gas pipes or any underground conduits that may suffer if joints are opened, care must be taken to prevent their alignment being disturbed. If the street is not very wide and the foundations of the buildings on either side do not get below the bottom of the trench there is apt to be settlement. In such cases it is customary to require the contractor to leave bracing and timbers in place to act as retaining walls until the filling settles and can take care of the pressure. Too many cross braces can not be left in, for it will interfere with the settlement of the earth. Lumber for such purposes does not have to be first-class. Care is to be taken that the contractor does not persuade the man in charge to leave too much in place. As a usual thing he gets a good price for such material and is anxious to leave it and be paid for it as it is likely to be left on his hands after the work is done. It can be used only for similar work.

SINKING OF PAVEMENTS OVER TRENCHES.

Careful filling of trenches with the earth thrown back in thin layers, dampened and tamped, will go far towards preventing sunken places in pavements over sewer and water pipe trenches and other similar excavations.

When trenches, however, have been opened in paved streets having a concrete base, it is a good plan to cover the trench with a reinforced concrete slab. To do this trim the edges of the concrete base on an angle for the lower half of the thickness and then flat for a few inches more, to form a berm. Fill in to the original thickness with concrete reinforced in the bottom.

FLOW OF WATER.

The following table is taken from the catalogue of a sewer-pipe company and is so common a feature in such publications that it can hardly be new to the readers of this book. The formula used in calculating it is an old and simple one, no longer used except for tile drainage and second quality sewer pipe used for drainage purposes. The table gives fairly reliable results, however, and is useful for pipe culverts.

CARRYING CAPACITY--GALLONS PER MINUTE.

Size of Pipe.	1 in. fall per 100 ft.	2 in fall per 100 ft.	3 in. fall per 100 ft.	6 in. fall per 100 ft.	9 in. fall per 100 ft.	1 foot fall per 100 ft.	2 feet fall per 100 ft.	3 feet fall per 100 ft.
3 inch.	9	12	15	22	27	31	44	54
4 "	20	28	35	50	62	71	101	124
6 "	63	89	111	156	194	224	317	389
8 "	140	198	246	348	432	499	706	864
9 "	196	277	339	480	595	687	971	1180
10 "	261	369	457	648	803	928	1310	1610
12 "	432	612	758	1070	1330	1530	2170	2660
15 "	800	1130	1400	1980	2450	2830	4010	4910
18 "	1320	1860	2310	3260	4040	4660	6590	8080
20 "	1720	2500	3060	4330	5305	6130	8660	10610
24 "	2910	4110	5035	7191	8810	10270	14520	17790
27 "	4020	5680	6960	9840	12050	13920	19680	24110
30 "	5380	7618	9320	13180	16140	18640	26350	32280
33 "	6950	9840	12050	17040	20865	24090	34070	41730
36 "	8800	12450	15210	21565	26410	30500	43130	52820

The standard formula is the Chezy formula.

$$V = c \sqrt{r s}$$

where V = velocity in feet per second.

c is a co-efficient found by means of Kutters' formula.

r is the hydraulic mean radius found by dividing the area of the water (cross section) by the wetted perimeter.

s is the fall in feet divided by the length in feet.

Old hydraulicians tried to secure a simple formula which would be generally applicable. It was found that there was a fairly constant relation existing between slope, area and velocity, for water

is inclined to run down hill and the law of its flow is known. Friction modified the flow so the area of the stream was a factor

Kutter's formula.

$$C = \frac{41.6 + \frac{.00281}{s} + \frac{1.811}{n}}{1 + \frac{\left(41.6 + \frac{.00281}{s}\right) \times n}{\sqrt{r}}}$$

Modified for ordinary use.

$$C = \frac{41.6 + \frac{1.811}{n}}{1 + \left(\frac{41.6\,n}{\sqrt{r}}\right)}$$

Flynn's simplified Kutter.

$$C = \frac{K}{1 + 44.41 \times \frac{n}{\sqrt{r}}}$$

$$V = \left\{\frac{K}{1 + 44.41 \times \frac{n}{\sqrt{r}}}\right\} \sqrt{rs}$$

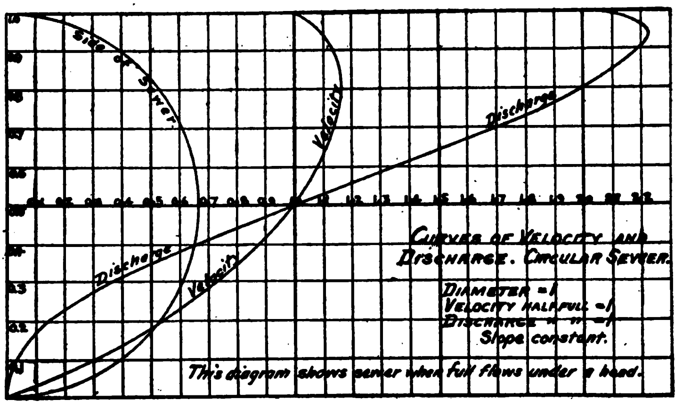
Following values of K apply only to pipes and conduits (not earthen channels).

n	K	n	K	n	K
.009	245.63	.012	195.33	.017	150.94
.010	225.51	.013	183.72	.020	134.96
.011	209.05	.015	165.14	.0225	124.90

as was the wetted surface of the channel and its length. For straight, clean, smooth pipes a fairly good formula could be used,

but in channels differing from such pipes so many elements of retardation entered in that Chezy introduced into the general formula his co-efficient C and recommended certain values. The extensive experiments of two Swiss engineers, Ganguillet and Kutter, gave us a formula with which to obtain c.

The formula is very complicated and diagrams and tables have been extensively used to lighten the labor involved. The second form shown is one that gives results close enough for the ordinary work of calculating drains and sewers. The third form is one used by Flynn to calculate his tables in Van Nostrand's Science Series Nos. 67 and 84. He extended these tables in his larger and later work, "Irrigation Canals, etc.," but it is now out of print and the plates destroyed.



It will be seen that in attempting to find a value for the co-efficient c, another co-efficient must be assumed. This is known as n, or the co-efficient of roughness. It varies as follows (Trautwine):

Sides and bottom of channel lined with well-planed lumber..	.009
Neat cement (also glazed pipes and very smooth iron)......	.010
Concrete, 3 sand, 1 cement (also smooth iron).............	.011
Unplaned lumber and ordinary iron pipes....................	.012
Ashlar or brickwork..	.013
Rubble	.017

CHANNELS WITH IRREGULAR CROSS SECTION.

Canals in very firm gravel	.020
Canals and rivers, fairly uniform cross section, slope and direction, fairly good order, free from stones and weeds.	.025
Having stones and weeds occasionally	.030
In bad order and condition, overgrown with vegetation and strewn with stones and detritus	.035

Two diagrams are presented here for illustrating the relations of flow and diameter in circular conduits. The first shows that the theoretical capacity of a pipe is 1.07 times the full capacity.

The diagrams are made from some in use in Chicago and other cities. The diagram showing velocity and quantity is calculated for pipe sewers flowing full. It is useful and saves much tedious labor in computing flow. Similar diagrams can be made for brick sewers and for egg-shaped as well as circular. The sizes given, however, are those commonly used in small places.

The quantity of water carried by a closed or open channel is, of course,

$$Q = av$$

where Q = cubic feet of water per second.

a is area of channel in square feet.

v is velocity in feet per second.

Colby's Sewer Computer is a slide rule graduated after Kutter's formula, the co-efficient n being taken at 0.013. It gives the relations between discharge, diameter and grade for round sewers from 6 inches to 20 feet in diameter and for egg-shaped sewers from 12x18 inches to 12x18 feet, and the grades for either from 0.05 to 20 per cent. The rule is 20 inches long. The price is $10.00.

Crane's Sewer Slide Rule is based on McMath's formula for amount of storm water and Kutter's formula for capacities for circular sewers from 6 to 180 inches diameter and egg-shaped sewers from 18 to 60 inches horizontal diameters, ratio of radii being 3 : 2. The rule is 10 inches long. The price is $2.00.

In estimating the size of drains it was formerly the custom to allow one inch of rainfall per hour, as it amounted to almost exactly one cubic foot per second per acre.

The local rainfall must be a factor and the use of storm water formulas is not to be commended unless they are used with great judgment. It is not always easy to secure good local rainfall records. The first effort made should be in the way of correspondence with the Weather Bureau and the State University. If

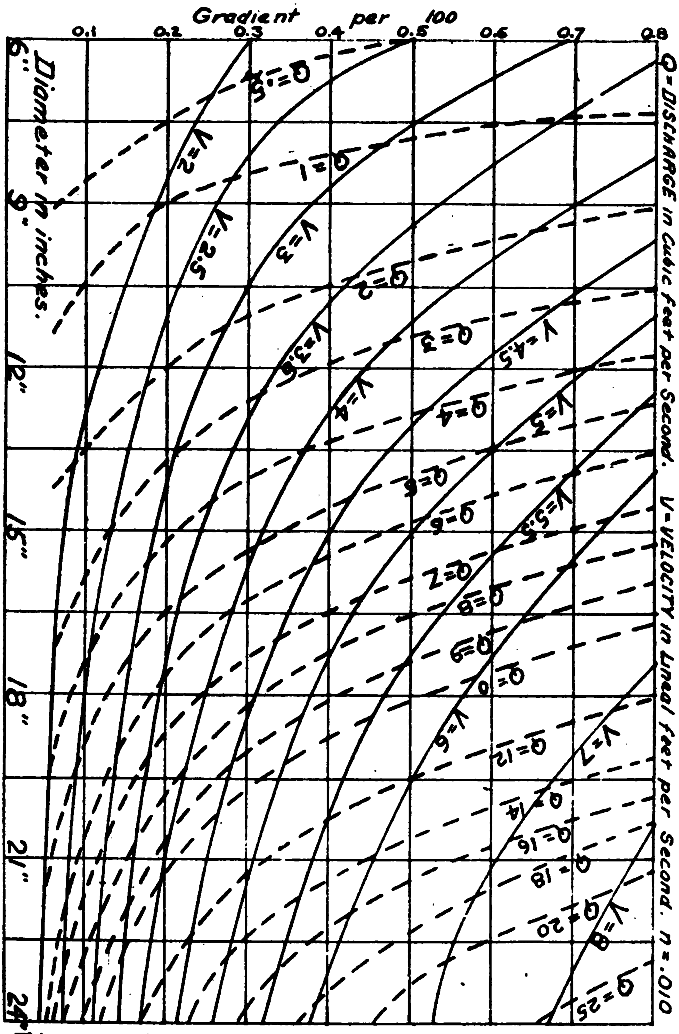


Diagram for flow in PIPE SEWERS. Kutter's Formula

no help can be obtained from those sources, and the drains can not wait ten or twenty years, the oldest inhabitants may be pressed into service.

If 10 per cent of the heavy rains recorded fall in thirty minutes, then a thirty-minute rainfall is a good guide in designing a main storm water drain in a somewhat closely built residence district. Fifteen minute rains should be taken into consideration in planning drains for a well-paved business district.

For ordinary cases, two inches of rainfall per hour should be estimated. When estimating the amount of water to be disposed of there must be taken into consideration the slope of the surface, the proportion of impermeable area, the average rate of precipitation in cubic feet per second per acre, and the drainage area in acres.

A very valuable paper was read before the Western Society of Engineers, February 7, 1906, on the area of water ways for railroad culverts and bridges and was published, together with the discussion, in the April number of the proceedings. This can be obtained from the secretary, 1734 Monadnock block, Chicago, Ill., for fifty cents. It contains much of value on the subject of culverts that will be interesting to city engineers.

Slope plays a large part in the flow of water from a certain area into the drains. In a city having many hills the water reaches the drain sooner than where the surface is flat and the slope light. In hilly places it may take only one and one-half to two times the duration of the storm to carry off the water. In a city very flat and with extremely light slopes it may take from three to five times the duration of the storm for all the water to reach the drain. When the point of saturation is reached, all the flow goes to the sewers, so a proper formula must take into account this matter of saturation of ground. A long light storm may tax a drain more severely than a short heavy burst.

The following rules are in common use for culvert work:

The following is much used on railroads:

$$S = C \sqrt{a}$$

where S is the sectional area of the culvert in square feet.

C is a constant taken as 3 for a sandy porous soil; 4 for a flat and partly porous surface; 5 for a partly porous surface where the

rains are heavy, and 7 where the rainfall is very heavy and the slopes steep and bare.

a is the area in acres to be drained.

The Fanning Formula is:

$$Q = 200\ A^{\frac{5}{6}}$$

where Q is the discharge in cubic feet per second and A the drainage area in square miles.

Using the same notation the following formula is quite widely used in irrigation works and for railroad purposes:

$$S = C \sqrt[4]{A^3}$$

in which C is 0.66 for steep and rocky ground; 0.33 for rolling ground when the length of the valley is 3 times the width; 0.2 when the length of the valley is about 5 times the width.

Nearly all engineers have given up the attempt to make a general formula do, as conditions vary so greatly, but the formula in most common use in cities (as a guide merely to indicate a line of study of the subject) is the Burkli-Ziegler, as follows:

$$Q = R\ C \sqrt[4]{\frac{S}{A}}$$

where C is a constant varying from 0.75 for paved streets and 0.31 for macadamized streets to 0.15 for a fairly porous soil.

R is the average rate of rainfall (during heaviest fall) in cubic feet per second per acre.

S is the general slope of the area per 1,000.

Q is equal to the cubic feet per second per acre reaching the drains.

A is the drainage area in acres.

The McMath formula was devised for use in St. Louis and any city similarly situated can use it with a proper value of R, which at St. Louis is 2.75 inches.

$$Q = R\ C \sqrt[5]{\frac{S}{A}}$$

The first rules and formulas given may be used for culverts and drains in the outlying districts, but for thickly settled parts of cities, some local modification of the last two formulas should be used, in the absence of anything better.

A sewer should have a self-cleansing velocity, and this is not far from $2\frac{1}{2}$ feet per second.

Baumeister gives the following empirical formula for the minimum grade:

$$\text{Minimum grade per cent} = \frac{100}{5\,d + 50}$$

where d is the diameter in inches of a circular sewer or the diameter of the lower part of an egg-shaped sewer.

Colonel Moore gives the following for a limiting velocity of 2.5 feet per second:

$$H = \frac{7.56}{2\,R}$$

where H is the fall in feet per mile and R is the hydraulic mean radius, the diameter, of course, being assumed.

In planning a sewerage system it is common to figure that six gallons of sewage per capita, in the district served, will reach the sewer each hour. With an ordinary town the population will vary from twenty to sixty per acre. The greatest density in any certain district is sometimes taken as the maximum density of the outlying districts for the next twenty years, and the district with maximum present density is assumed to increase 50 per cent in that time.

Such methods are of course empirical, but the matter of future growth is one hard to estimate because of local conditions. The statistics of the U. S. Census Bureau show that in ten years the average increase in population of American cities was over 30 per cent. The largest increase was in places having less than ten thousand inhabitants, the increase there being nearer 36 per cent.

When building sewers in wet ground it is a good idea to use perforated invert blocks. They provide channels for the subsoil water to escape during construction and are a great convenience. If it is desired to have them act always as drains, proper arrangements can be made at manholes to connect them across the bottom.

Wherever possible the tops of all sewers entering a manhole should be at the same elevation. This insures a flow in the smaller pipes when the outlets are half full.

When a pipe sewer enters a manhole at a considerable height

above the bottom it is usual to put a T in the bottom of the pipe just outside the manhole and run a vertical pipe from it to a point where it can enter the manhole near the bottom with a curved elbow The short section between the T and the inside of the manhole will only be used for inspection purposes or may be of service when the sewer is crowded and running full and fast.

Inverted siphons are used occasionally, but it is best to avoid them if possible. An inverted siphon usually has a manhole at each end and the pipes are laid straight from one to the other to admit of easy inspection. As a sewer is usually planned for future needs an inverted siphon is usually built with two or more pipes of half the diameter of the sewer. They are generally of metal and have gates at the upper end. One pipe is used until it is seen to be crowded, when another pipe can be called into service. The details should be planned by a specialist in sewer design.

The writer has frequently been compelled to let down a water main when it was at an elevation to interfere with the laying of a sewer. Assuming the pipe to be not more than twelve inches in diameter the process is to excavate underneath the pipe and leave pillars of earth at the joints, for a distance of from forty to sixty feet each side of the sewer. The pipes should be full of water while the work is being done.

When the bed is ready a man should be stationed at each pillar of earth and all should commence undercutting at the same time. The pipe will sink slowly into its new position and the caulkers should at once begin recaulking the slightly opened joints.

If the drop will be considerable the pipe can be held by chains passing over heavy timbers laid across the trench and lowered or raised by the chains by means of house raising jacks. Great care must be taken to work rapidly and uniformly, without haste, to avoid breaking the pipe open at the joints. If the pipe is to be raised to go over the sewer instead of underneath, brick piers must be built under each joint and the space underneath filled with sand flushed into place. It is usually better and more convenient to lower a pipe than to raise it.

Overflows are occasionally required to carry off an excess of storm water. The writer has frequently run across them where the engineer has run a small pipe as an overflow from the top of a pipe sewer to the bottom of a storm or overflow sewer.

When the overflow sewer filled it backed into the other. The bottom of the overflow pipe should always enter the overflow drain at the top, or be a few inches over it, and drop in through a slant.

The constant flow is termed the "foul flow." This must of course be taken to a disposal plant, but when augmented by large quantities of drainage water the dilution is so great that the temporary excess can be led off and disposed of where the surface water is generally discharged. This is accomplished by separating devices so arranged that a certain number of cubic feet of foul flow per second is taken care of, after which the excess is turned off into other channels.

The most simple form is a pipe leaving a manhole at such a height that when the outlet sewer is running full the upper pipe will take the surplus.

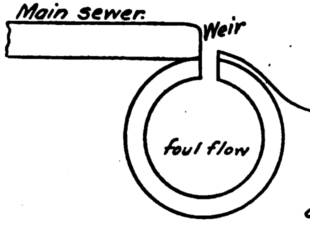
Such a simple device is not always possible, and the two following described are often used. One comes in one of two forms; a small sewer pipe with an overflow weir discharging into a larger pipe; and, a large pipe having a small outlet that takes all the foul flow and in time of storm takes a maximum flow, after which the rest goes into the remainder of the length of large pipe.

In the first case the small pipe is carried in the wall of a chamber for the length of the weir and is halved for that length or else runs in a channel with a level edge at the top of the pipe. The edge of the weir is at such a height that when the smaller pipe is carrying the maximum "foul flow" all the rest of the liquid goes into the larger pipe.

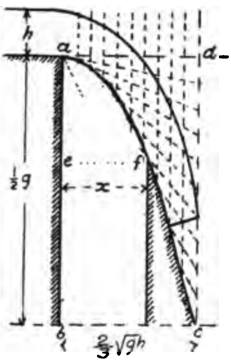
In the second form there is a chamber through which the flow passes. The bottom is so arranged that on one side it is shaped like the larger pipe and on the other side is level for the whole length, with the level edge a little lower than the bottom of the pipe at the outlet. The crest is at least three inches wide and perfectly flat. The bottom slopes toward this three-inch width from all directions. The edge is at the height of the middle of the smaller pipe and parallel with the line of flow. As the liquid enters the chamber it is of course directed to the edge over which it falls and thus flows away in the smaller channel.

The edge forms the bottom of an orifice through which the liquid flows. The dimensions must be such that the maximum foul flow will pass through, and no more, it being assumed that the small pipe has been figured to carry it. When the large pipe

SEPARATING WEIR. BRADFORD WATER WORKS.



Parabolic jet. Distance water is projected depends on depth of water on weir and consequent velocity.



Let h be head on weir. Then mean velocity over weir can be assumed as $= \frac{2}{3}\sqrt{2gh}$

Let x = width of orifice $e\,f$

y = difference of level $a\,e$ of two edges.

If particle passes from a to f in t seconds $y = \frac{1}{2}gt^2$

$x = \frac{2}{3}\sqrt{2gh} \times t \quad \therefore y = \frac{9}{16} \cdot \frac{x^2}{h}$

This gives width for any given difference in level which jet will just pass over with head (h).

If there is a velocity of approach (h) must include the head necessary to give that velocity, which is $(\frac{V}{2g})^2$, if V is the velocity of approach in feet per second.

In order to describe the path of the jet set off $a\,b$ vertically $= \frac{1}{2}g$ on any scale, and $b\,c$ horizontally $= \frac{2}{3}\sqrt{gh}$ divide $a\,d$ and $d\,c$ into any equal number of equal parts, join a with the divisions on $d\,c$, and verticals through the divisions on $a\,b$. The intersections of these lines will give the parabolic path of the underside of the jet.

from Col Moore's Sanitary Engineering.

is flowing full there will be a head on the orifice equal to the diameter of the pipe, less the half height of the orifice, and plus the velocity head in the large pipe. Five times the square root of this head in feet will give the velocity in cubic feet per second flowing through the orifice.

The height should be about two or three inches. Assuming a height, the length can be calculated, for the discharge, multiplied by the velocity, gives the area. The orifice is cut in a piece of sheet iron which is set in place. This rule is closely approximate.

The plan supposes a chamber set on the line of a large pipe and the smaller pipe leaves one side of the chamber, being for a short distance parallel with the larger pipe. The depth of flow in the larger pipe when carrying the maximum foul flow should be calculated. Set in the chamber a diversion dam with the top at this height so all the flow will be directed toward the orifice until the maximum flow is exceeded. This diversion dam should run on a curve crossing the chamber in such a manner that it ends at the far end of the orifice. The top of the orifice should be about equal in elevation with the top of the dam.

The accompanying illustration of a diversion weir used in England is of interest in this connection.

In some cities a form of inlet known as a "Park inlet" is used in gutters. On steep grades these inlets have proven useless in times of heavy storm, for the water flows over the bars without a ripple. A study of the Bradford weir will show that the spacing between the bars should vary with the inclination of the street and the depth of water in the gutter. An inlet of stock pattern having bars in the gutter bottom can not be used on all grades.

With separating devices such as above described, the accumulations of foulness go into the foul flow pipes before the depth becomes so great that the overflow pipe takes it. With the slightest lessening in head and velocity the water begins to pass off into the foul flow pipe where it belongs.

Occasionally a sewer, if carried on a uniform grade, will discharge into a body of water at a point above the surface. In such cases it is a good plan to have a drop, like that mentioned for deep manholes, so the constant flow will be below ordinary water level. The end of the upper pipe can have a light flap door over it which will be forced open in times of storm when there is a heavy flow and the lower outlet can not take it.

Circular Sewers.—Brick, 2¼ in. x 4 in. x 8¼ in. Mortar Joints, ½ in. Three barrels cement to one yard of mortar. One part cement, two parts sand.

DIAMETER.	Area Sq. Ft.	Brick per Running Foot of Sewer.			Cubic Yds. Occupied by Sewer per Foot.			Cubic Yards of Mortar per Running Foot.		
		1 Ring	2 Rings	3 Rings	1 Ring	2 Rings	3 Rings	1 Ring	2 Rings	3 Rings
2 feet........	3.14	42	100	172	.19	.34	.51	.032	.073	.124
2 " 6 inches	4.90	51	118	199	.29	.44	.63	.037	.086	.144
3 "	7.06	59	136	227	.39	.57	.78	.045	.098	.165
3 " 6 inches	9.62	68	155	255	.51	.71	.94	.049	.112	.185
4 "	12.57	77	173	282	.64	.85	1.10	.056	.125	.205
4 " 6 inches	15.90	86	191	310	.78	1.10	1.29	.062	.138	.225
5 "	19.63	95	209	338	.94	1.20	1.50	.069	.152	.245
5 " 6 inches	23.76	104	228	365	1.10	1.40	1.71	.075	.179	.265
6 "	28.27	113	246	393	1.30	1.60	1.94	.083	.185	.285
6 " 6 inches	33.18	122	264	421	1.50	1.82	2.17	.089	.192	.306
7 "	38.48	130	282	448	1.70	2.06	2.45	.094	.204	.325
7 " 6 inches	44.17	139	301	476	1.94	2.32	2.72	.100	.218	.346
8 "	50.26	148	319	504	2.18	2.57	3.00	.107	.231	.366
8 " 6 inches	56.74	157	337	532	2.45	2.85	3.32	.114	.244	.386
9 "	63.62	166	356	559	2.70	3.16	3.62	.120	.258	.406
9 " 6 inches	70.88	175	374	587	2.96	3.50	4.00	.127	.272	.426
10 "	78.54	184	392	615	3.26	3.80	4.30	.133	.234	.447
10 " 6 inches	86.59	......	.....	....	3.65	4.13	4.68	....	.....	.....
11 "	95.03	......	.....	....	3.97	4.50	5.07	....	.....	.....
11 " 6 inches	103.87	......	.....	....	4.32	4.85	5.45	....	.....	.....
12 "	113.10	......	.....	....	4.68	5.25	5.78	...	.....	.....

Egg-Shaped Sewers.—Long diameter equals 1½ times short diameter.

Brick and mortar same as for circular sewers.

SIZE.	Area Sq. Ft.	Brick per Running Foot of Sewer.			Cubic Yds. Occupied by Sewer per Foot.			Cubic Yds. of Mortar per Running Foot.		
		1 Ring	2 Rings	3 Rings	1 Ring	2 Rings	3 Rings	1 Ring	2 Rings	3 Rings
12 x 18 inches..	1.15	28	76	147	.12	.17	.34	.020	.055	.106
14 x 21 " ..	1.56	31	84	158	.15	.21	.38	.023	.061	.115
16 x 24 " ..	2.04	35	89	170	.18	.25	.43	.026	.065	.123
18 x 27 " ..	2.58	38	99	181	.21	.29	.47	.028	.072	.131
20 x 30 " ..	3.19	42	106	193	.24	.32	.52	.030	.077	.140
22 x 33 " ..	3.86	46	114	206	.27	.38	.57	.033	.083	.149
24 x 36 " ..	4.60	49	121	217	.31	.41	.63	.036	.088	.157
26 x 39 " ..	5.40	53	129	229	.35	.45	.68	.038	.094	.166
28 x 42 " ..	6.26	57	136	241	.39	.50	.74	.041	.099	.174
30 x 45 " ..	7.19	60	144	252	.43	.55	.80	.043	.102	.182
32 x 48 " ..	8.18	63	151	263	.53	.60	.86	.046	.110	.191
34 x 51 " ..	9.23	67	159	276	.58	.66	.93	.048	.114	.200
36 x 54 " ..	10.35	70	166	287	.63	.71	1.00	.051	.120	.207
38 x 57 " ..	11.53	74	174	299	.69	.78	1.06	.053	.126	.216
40 x 60 " ..	12.78	77	181	311	.75	.84	1.14	.056	.132	.225
42 x 63 " ..	14.09	81	188	323	.81	.90	1.21	.059	.137	.235
44 x 66 inches.	15.46	84	196	335	.86	.96	1.28	.061	.142	.243
46 x 69 "	16.90	88	203	346	.94	1.04	1.35	.064	.148	.251
48 x 72 "	18.40	91	210	357	1.00	1.11	1.45	.066	.152	.258
50 x 75 "	19.96	95	218	369	1.08	1.18	1.54	.069	.159	.267
52 x 78 "	21.59	98	226	381	1.15	1.26	1.62	.071	.164	.276
54 x 81 "	23.28	102	233	393	1.22	1.33	1.71	.074	.169	.285
56 x 84 "	25.04	105	241	404	1.30	1.40	1.79	.076	.174	.293

Table Showing Cubic Yards of Excavation Required Per Lineal Foot in Trenches of the Following Dimensions.—Depth in Feet.

Width	4	6	8	10	12	14	16	18	20	22	24	26
2 feet	0.30	0.44	0.59	0.74	0.89	1.04	1.18	1.33	1.48	1.63	1.78	1.93
2½ feet	0.37	0.53	0.74	0.93	1.11	1.30	1.48	1.67	1.85	2.04	2.22	2.41
3 feet	0.44	0.66	0.89	1.11	1.33	1.55	1.78	2.00	2.22	2.44	2.66	2.89
3½ feet	0.52	0.78	1.04	1.30	1.56	1.82	2.07	2.33	2.59	2.85	3.11	3.37
4 feet	0.59	0.89	1.18	1.48	1.78	2.07	2.37	2.67	2.96	3.26	3.55	3.85
4½ feet	0.66	1.00	1.33	1.67	2.00	2.33	2.67	3.00	3.33	3.67	4.00	4.33
5 feet	0.74	1.11	1.48	1.85	2.22	2.59	2.96	3.33	3.70	4.07	4.44	4.81
5½ feet	0.82	1.22	1.63	2.03	2.44	2.85	3.26	3.67	4.07	4.48	4.89	5.30
6 feet	0.89	1.33	1.78	2.22	2.66	3.11	3.55	4.00	4.44	4.89	5.33	5.78
6½ feet	0.96	1.44	1.93	2.40	2.89	3.37	3.85	4.33	4.81	5.30	5.78	6.26
7 feet	1.04	1.55	2.07	2.59	3.11	3.63	4.15	4.67	5.19	5.70	6.22	6.74
7½ feet	1.10	1.66	2.22	2.77	3.33	3.89	4.44	5.00	5.55	6.11	6.67	7.22
8 feet	1.18	1.78	2.37	2.96	3.55	4.15	4.74	5.33	5.92	6.52	7.12	7.70

NO. FEET STANDARD PIPE IN CAR LOAD. (24,000 LBS.)

3 inch .... 3,400 feet.	10 inch .... 800 feet.	24 inch .... 180 feet.
4 inch .... 3,000 feet.	12 inch .... 600 feet.	30 inch .... 120 feet.
5 inch .... 2,400 feet.	15 inch .... 400 feet.	33 inch .... 90 feet.
6 inch .... 1,600 feet.	18 inch .... 320 feet.	36 inch .... 80 feet.
8 inch .... 1,200 feet.	20 inch .... 270 feet.	
9 inch .... 900 feet.	22 inch .... 200 feet.	

ESTIMATES FOR SEWER WORK.

The cost of hand digging in ordinary earth with labor at 15 cents per hour and foreman at 25 cents per hour is practically 20 cents per cubic yard for a trench six feet deep; 25 cents for eight feet; 30 cents for ten to twelve feet; 35 cents for fourteen feet; 40 cents for sixteen to eighteen feet; 45 cents for twenty feet deep. The above figures are actual cost without profit being added. Back filling will be additional and depends upon the method adopted for doing it. A team with driver, and man to assist holding the scraper, should scrape in about fifty yards in ten hours, of easy

COMPARATIVE COSTS OF TILE AND BRICK SEWERS.

TILE. *When using this table add cost of tile.*

Size of Pipe	Width of Trench	6 ft. Digging	6 ft. Laying and Cement	8 ft. Digging	8 ft. Laying and Cement	10 ft. Digging	10 ft. Laying and Cement	12 ft. Digging	12 ft. Laying and Cement	14 ft. Digging	14 ft. Laying and Cement	16 ft. Digging	16 ft. Laying and Cement
		Costs per lineal foot.											
27 inch	3' 2"	$0.20	$0.11	$0.26	$0.12	$0.38	$0.13	$0.52	$0 14	$0.65	$0.15	$0.85	$0.16
30 "	3' 6"	0.22	0.14	0 30	0.16	0.43	0.18	0.59	0 21	0.72	0.24	0.92	0.27
33 "	3' 9"	0.25	0.17	0.33	0.19	0.46	0.21	0 63	0.24	0.77	0.28	1.00	0.35
36 "	4' 2"	0.28	0.20	0.36	0.22	0.50	0.25	0.67	0.28	0.82	0.32	1.10	0.36

BRICK.

Size of Sewer	Width of Trench	6 ft. Digging	6 ft. Material and Labor	8 ft. Digging	8 ft. Material and Labor	10 ft. Digging	10 ft. Material and Labor	12 ft. Digging	12 ft. Material and Labor	14 ft. Digging	14 ft. Material and Labor	16 ft. Digging	16 ft. Material and Labor
		Costs per lineal foot.											
2' × 3' egg.	3' 8"	$0.27	$1.80	$0.35	$1.80	$0.48	$1.85	$0.65	$1.90	$0.80	$1.95	$1.05	$2.00
$2\frac{1}{2}$' × $3\frac{1}{2}$ "	4' 2"	0.33	2.00	0.41	2.00	0.55	2.05	0.73	2.10	0.90	2.15	1.15	2 20
3 ft. round	4' 8"	0.36	1.80	0.45	1.80	0.60	1.85	0.70	1.90	0 98	1.95	1.25	2.00

material. Men with shovels and picks should backfill about ten yards each.

On the same basis the excavation alone in tough clay will be practically 30 cents per cubic yard for six-foot trenches; 37 cents for eight feet; 45 cents for ten to twelve feet; 52 cents for fourteen feet; 60 cents for sixteen to eighteen feet; and 67 cents for twenty feet deep.

Hard pan, 50 cents per cubic yard for six-foot trench; 62 cents for eight feet; 75 cents for ten to twelve feet; 87 cents for fourteen feet; $1.00 for sixteen to eighteen feet; $1.12 for twenty feet deep.

In estimating sewer work add to the above the cost per foot of pipe; one cent per inch of diameter for hauling, laying, cement, etc.; 25 per cent profit on the labor items and 15 per cent profit on the cost of material and laying. Add the cost of backfilling at about 15 cents per cubic yard.

The tables of comparative cost of tile and brick sewers are taken from the catalogue of the Blackmer & Post Co., and are said to be based on the following prices, with favorable conditions of soil and weather.

Tile.—Labor 22½ cents per hour. Pipe layers, 30 cents per hour. Cement, 80 cents per barrel. Sand $2.00 per yard. Mortar for pipe, 1 cement, 1 sand.

Brick.—Labor, 22½ cents per hour. Brick, $6.00 per M. Bricklayers, 35 cents per hour. Hod carriers, 30 cents per hour. Mortar men, 28 cents per hour. Mortar for brick work, 1 cement, 3 sand.

* Prices today for such work would be more nearly as follows: Laborers, 25 cents; mortar men, 30 cents; hod carriers, 35 cents; pipe layers, 35 cents; bricklayers, $1.00 per hour. Sand and cement according to locality. Brick from $9.00 to $18.00 per M.

A good mason will lay from three to four thousand brick per day. The accompanying tables of quantities of brick and mortar for round and egg-shaped sewers are believed to be correct:

WATER TIGHT MORTAR.

When laying pipe in a ditch having a flow of water it is customary to partly fill the joint with jute soaked in neat cement grout and fill the joint with a mortar of 1 to 1 cement and sand. Over the joint when filled wrap a strip of cloth like a bandage to

keep the water from washing out the cement before it is set. The admixture of a very small amount of plaster of Paris is advised by some, but the writer does not recommend it.

A better way is to mix pine tar and cement to the consistency of putty and ram into the socket with a caulking tool. The work must be done rapidly and the paste must not be allowed to get mealy. The pine tar can be washed off the hands with kerosene.

The following recipe for a water-resisting mortar was given in Cement, July, 1904: In 2 lbs of water dissolve 1/4 lb. of salt; add 1 lb. of potash lye; heat to from 85 to 100 degrees F.; mix 2 to 3 parts of cement to 1 part of sand; moisten with the salty potash mixture while warm and apply the paste immediately, for it sets in less than one minute. Or some powdered wood charcoal can be mixed with the sand and cement and the liquid added cold. The paste when in place can be painted with an oil varnish, the object of the charcoal being to hold the varnish.

See also the section on Lutes and Cements.

CHAPTER VII.

WATER SUPPLY.

One of the first questions asked by a possible resident, or manufacurer, who may locate in a growing town, is in regard to the water supply. He wants to locate in a place where he can get a plentiful supply of water for manufacturing purposes and for protection in case of fire. If there is a plentiful supply of water he also inquires about a sewer system, for one is needed to carry off the waste.

Water is needed for drinking, manufacturing purposes, laundries and baths, street sprinkling, sewer flushing, irrigating lawns, fire protection, etc., and if it is not good for all of these uses it is not a good commercial water. It may be all right for cooking and drinking yet unfit for manufacturing, or vice versa. It is difficult to get a water perfect in all respects, but good water of an average quality can generally be obtained in sufficient quantity for any small place at no great expense. If it is polluted or impure it must be purified, if it is found to be impossible to get a better supply by going a little farther.

Great attention is now paid to the purity of water in the United States. Good sources of supply are difficult to procure and some artificial purification is rendered necessary, for people today will not take readily the water their grandfathers would have been satisfied with.

There are two systems of filtering in vogue, the first called slow sand filtration, and by some the English system. The other, rapid filtration or the American system of mechanical filtration. In the slow sand filtration system the water is led into filter beds where it percolates slowly through the filtering medium. On the surface of the sand slime is formed. A felted slimy mass of algæ, and various bacilli, accumulates in this cultivation bed and here the main purification of the water takes place. It is therefore necessary,

for the proper working of the sand filter, that this jelly layer be formed, and the process of purification goes on by the action of the nitrifying organisms until the filter becomes clogged by the suspended impurities and the flow of water gets scanty. It is then cleansed and put in shape for further use by skimming off the surface layer and putting on a fresh coating of sand. The water is turned in again and allowed to waste until a new jelly has formed when the effluent is turned into the city mains. In some places a lot of the old sand is put back with the new in order to hasten the formation of the jelly. Great numbers of filter beds are required, as the work is done intermittently in order that the beds may be kept in the highest possible state of efficiency. The system of slow sand filtration is therefore expensive and is better suited to very large cities than to smaller places.

The mechanical system of filtration is an American invention and consists of tanks containing finely pulverized quartz as a filtering medium. A chemical coagulent is added to the water in small quantities to form the jelly and it is not therefore necessary to wait so long for the filter to get into action. When it requires cleaning the flow of water is reversed in the filter and by machinery the sand is stirred up until the water running out is clear. The water is set running the right way again, the coagulent added, and in a short time the filter is working at its full capacity. For a small town it is better than the slow sand filtration method and it may be better in larger places, but more experiments will have to be made before a positive opinion can be given.

The primary idea of a filter was a strainer where the suspended matter was taken out. When the matter was thoroughly understood it was found there was a bacterial action also and the ordinary household filter instead of being a protection was an absolute danger, for it cultivated colonies of dangerous bacilli. A household filter in which the filtering medium is a baked clay or porcelain is the only kind to use. Dealers often say the way to clean them is to take out the porcelain once a week and wash it. Such advice is dangerous. The only way to clean it is to boil it by placing in cold water after washing and putting in a pot on the fire and allowing the water to come to a boil and boil brisky until the porcelain is hot. Then let it cool slowly. If the porcelain is cracked get a new one.

Lake water is a doubtful source of supply. Ground well water

is sometimes safe to use, but is generally unsafe if taken from ground close to a large community. The well in the thickly settled community is usually dangerous and the open well can not be condemned in too strong terms. If a well is used it should be closed and the water pumped from it for ordinary use.

Driven wells are frequently used as a source of supply for a town and they are good if the quality of water is all right. For this reason when deciding to adopt the driven well system a careful examination should be made chemically and biologically of the water and an examination made as to the possible sources of supply of the sand and gravel bed into which the wells are driven. A large cistern may be constructed with several wells driven in the bottom of it. Water is then pumped from the cistern or the wells may be driven in a regular series and connected with a main pipe from which the water will be pumped.

When the quantity required is not great, the best system is by pumps, with a standpipe, or tank, containing at least twenty-four hours' supply. The tank furnishes the pressure except in case of fire when it is better to disconnect it and let the pump force the water directly into the supply main. Ordinarily the pumps need only be used to keep the tank filled and there should be some sort of electrical indicator in the pump house so the engineer need not pump too much and cause the tanks to overflow.

With a town of over 3,000 inhabitants a direct pumping system may be preferable, with several standpipes in different parts of town, if it is very hilly or broken. The standpipes will be supplied by the force main and each supply its own district. There should be standpipes or tanks to supply districts ordinarily supplied by direct pumping, in case of the pump being required to work in other districts when a fire breaks out and more pressure is needed. Each district can thus be as independent as though in different cities.

With a large city a gravity system may be less expensive than a pumping station, but it will require careful figuring in any event. With a gravity system reservoirs are generally used instead of tanks and standpipes. It is well to remember that when surface water from streams and lakes is stored in reservoirs that the reservoirs must never be covered, but should always be exposed to the light and air. When water from wells and underground sources is stored

in reservoirs it must be covered to exclude all light. This to prevent the growth of algæ.

Artesian wells are good enough in their way when no other source of supply is available, but it is seldom that a well can be obtained of sufficient flow to supply even a small place. A town considering the proposition of obtaining water from artesian wells must proceed slowly and carefully; in order that after the hole is bored and the pipes laid, the volume of water to depend upon will justify the expenditure of the money spent to secure it.

Salt water is used in sea side cities to sprinkle streets and has been found to be very much superior to fresh water for the purpose. It has been found of doubtful benefit in extinguishing fires, as a building well soaked with it never dries thoroughly.

A pumping plant should generally be in duplicate so in case of breakdowns there will be no stoppage of the supply. This is not so important where the plant does not have to work more than a few hours each day or for a day or so in the week. For small towns, and generally throughout the west where fuel is scarce, the gas or oil engine connected to a power pump is coming rapidly into favor. The writer has recommended their use and believes they are the best thing in many cases for the service. They are useful in larger places also where there may be isolated districts to serve of limited area. In such places a separate pumping station with elevated tank can be placed and the water pumped from the main to this tank, which communicates with the pipe system in the small district as an independent supply.

Again they may be used in towns where the water company has a contract to furnish a certain high pressure in case of fire and the pumps do not work constantly. The pumps may supply tanks or standpipes at a sufficient elevation to furnish a good pressure for domestic use. The smaller gas or oil, engine may pump from these tanks sufficient to fill a smaller tank at a higher elevation which can be connected with the main system of pipes in case of fire, a check valve preventing the backing of the water into the lower tank. As this tank for fire purposes may not be used once in six months and might contain water enough to last a half dozen fire streams an hour or two a small engine will do the work at a minimum of attention and expense.

In some favorably situated places good tank capacity is fur-

nished and large windmills are used. There is an oil or gas engine in reserve to use when the wind fails. A good windmill will cost nearly as much as an engine of the proper size. There is a great deal of economy resulting, however, when conditions are favorable.

Producer gas engines are coming rapidly into use and well repay investigation. Electricity is used as much today as steam power in many cities having electric plants.

QUANTITY OF WATER.

It is not safe to figure on less than thirty gallons per capita per day, and the amount in a manufacturing town may reach sixty to eighty gallons per day per capita. Estimates based on the total population. Some American cities use much more.

A leading authority has carefully investigated the use of water in American cities and his conclusions are that 60 per cent of the water is not accounted for. In Europe where there is more careful and judicious oversight it is stated that fully 90 per cent of the water is accounted for.

Too little care is exercised in laying water pipes. In the opinion of the writer (from actual experience) it pays to set stakes for the water and gas pipes as much as it pays, because it is absolutely necessary, for sewers. Settling strains play havoc with joints. For convenience in making joints it is usual to elevate water and gas pipes. When this is done the trench to the tops of the pipes should be filled with sand, flushed in with water to give the pipes a solid bearing.

Waste exists all through the system by reason of careless work in putting the pipes in place and also by reason of faulty work in making house connections. The writer has seen plumbers connecting houses when the main was of thin wrought iron and there being a leak under the saddle they beat around it with their hammers until the flow stopped—not adding anything to the excellence of the nearest joint in the main, which may have been defective at first

Waste also exists in the interior plumbing of the house and when a water works system is installed there should be a first-class ordinance passed to regulate this work and all cocks and faucets should be of a certain standard of excellence. But a very large part of the waste exists by reason of the householder being careless because he pays so much a month no matter how much he uses.

The only remedy is the introduction of meters. An immediate saving in running expenses is noticed. There is not always a reduction in revenue, but there is a saving of cost and a consequent increase in actual profits. The careful economical citizen does his best to reduce his water bill and after he becomes accustomed to the meter finds that he does not have to skimp, as the minimum meter charge allows him plenty of water for every ordinary purpose. Wherever the meter system has been introduced it has been favorably received and its use extended.

There has existed oftentimes a prejudice in the mind of the consumer against a meter for fear it will register in favor of the company, but a little reflection will show him that as it wears much water must pass through it without being registered, so if the new meter registers in his favor it will be apt to do so as it grows older. In some places a tank is placed in the water company's office which contains exactly ten cubic feet of water at ordinary temperature. A house meter is attached to the supply pipe and water measured into the tank before the eyes of the consumer and he can read the result himself. With a meter geared to 99 per cent there is no fear of the test not satisfying him and he can go with the man and see that same meter installed in front of his house on the supply pipe.

A report by the board of water commissioners of Hartford, Conn., said: "Meters act as mechanical inspectors of plumbing and as such are less objectionable to consumers than individual inspectors, as well as being more effectual and reliable."

It is possible to obtain in almost every city reliable house meters at moderate prices and their general introduction will reduce the cost of living and do away with enormous waste.

As a guide to the possible use of water for various purposes the following from the 1905 report for the city of Battle Creek, Mich. is interesting:

	Per cent	
Paid for by meter (12.2c per 1,000 gallons, average)	53	$23,000
Paid for, not metered	5	2,200
Parks, public buildings, not schools	8	3,500
Schools, including lawns	6	2,600
Drinking fountains for horses	5	2,200
Flushing sewers	0.5	200

Blowing off hydrants	0.5	200
Wetting down new trenches	2	800
Fires	4.5	2,029
Slip of pumps	3	1,300
Under registration of meters	6.5	2,800
Leaks	6	2,600
Totals	100	$43,429

The percentage of taps metered in 1905 was 88, or 3,279 out of 3,723. The average daily water consumption and waste per capita was 52 gallons. The meter rates range from 7 to 13 cents per 1,000 gallons, with a minimum annual rate of $3.00. All new water takers are required to put on meters, and all who change pipes or fixtures or added thereto. The writer thinks some guessing was done in apportionment. The fire use seems much too great.

In a number of municipally owned plants water is apparently sold to the consumers at a low price because rates have been lowered and many departments of the city get water free.

To be businesslike all departments using water should be charged for it and a sinking fund established to maintain the plant. In an interesting circular prepared by the Pitometer Company there is a discussion on the subject of waste through underground pipes, although waste is carefully looked after above ground in the matter of salaries, cost of fuel, etc.

The fact that what one city uses is not a criterion for another place is mentioned, and the following is quoted:

"The water used by 2,553 families in Providence, R. I., was measured for one year. Five persons counted to a family, make a total of 12,765 people. By actual measurement:

167	families	used	but	6.15	gallons	to	a	person.
237	"	"	"	8.20	"	"	"	
361	"	"	"	10.25	"	"	"	
445	"	"	"	12.30	"	"	"	
446	"	"	"	14.35	"	"	"	
462	"	"	"	16.40	"	"	"	
435	"	"	"	18.27	"	"	"	

And yet we find American cities publishing the information, year

after year, that their works are actually supplying 150 to 300 gallons each day to each person in the city!

The question is then taken up of the Chicago water supply, which in 1903 amounted to 160 gallons per capita. Estimating the actual consumption at more than three times the highest average in the above table, or at 60 gallons, we have left a per capita of 100 gallons, or a total loss of 187 million gallons per day actually raised by pumps from the lake.

Cities and private companies in England allow no such waste. By constant care, and by inspections judiciously made, as a regular part of administration, they keep the per capita consumption down to very different figures. For instance: In Liverpool, for all purposes, 38.346 gallons per capita, of which only 22.18 per capita is set down for domestic uses of all sorts. There is no restriction of use by the consumers, day or night. In Manchester, 35.67 gallons per capita, of which 19.67 gallons is used for domestic purposes, 16 gallons for trade. In Birmingham, 29.52 gallons per capita. In London, 42.43 gallons per capita. These figures can be duplicated to any extent, but, it will be said, "This is in England." Let us take the city of Providence, R. I., again: In 1892 the per capita had increased to the alarming extent of 65¼ gallons per capita. In 1894 this had been reduced to 51⅓ gallons by taking pains to discover where this great loss was made! These figures include all the water delivered from the works for all purposes. In the town of Ealing, England, with a population of 25,000, the per capita was reduced from 43 gallons per capita to 30.75 gallons per capita, by an eight weeks' campaign of the inspectors!

Losses through defective mains or service pipes tend to increase in amount rapidly. The history of the Chicago works shows this fact very clearly. Thirty-five gallons per capita was the original estimate of the engineer who designed the plant. In 1860 the actual per capita was 43 gallons; in 1870 this had increased to 73 gallons; in 1875 to 100 gallons; in 1890 to 138 gallons; in 1900 it had reached 200 gallons; while in 1903 we find a per capita of 160 gallons after deducting all metered water."

Much of the difference is caused by leaky and defective mains and connections. It has to be admitted, however, that sometimes water is stolen outright. Nearly every man experienced in water

works maintenance can tell of private connections made by tunneling to street mains, and of by-passes around meters.

It pays to install meters on every connection and also on mains, to divide the city into districts. A careful investigation from time to time will locate all losses closely and remedies can be applied. If pumps register a certain amount of water delivered to the mains and meters register a certain amount used, there must be a better way of accounting for differences than by estimating uses for public purposes.

Twice the writer has been called upon to devise means of procuring a large supply in towns bonded to the limit, and yet suffering from a shortage of water. A careful investigation revealed such losses that when the piping system was put in good shape and all connections metered, the per capita consumption as shown by pumping records, was cut almost in two. Other engineers have had similar experiences.

GENERAL USE.

Good fire hose will cost at least 80 cents a lineal foot. The life of fire hose is not long and when it is observed how rapidly effective pressure is lost by long streams no argument is required to show that large mains are an advantage in a water works system. The following table is instructive:

FIRE STREAMS.

Pressures required at nozzle and at pump, with quantity and pressure of water necessary to throw water various distances through different sized nozzles, using 2 1-2 inch rubber hose and smooth nozzles.

G. A. Ellis, C. E.

SIZE OF NOZZLES.	1 INCH.				1⅛ INCH.				1¼ INCH.				1⅜ INCH.			
Pressure at nozzle	40	60	80	100	40	60	80	100	40	60	80	100	40	60	80	100
*Pressure at pump or hydr'nt 100 ft. 2 1-2 in. rubber hose	48	73	97	121	54	81	108	135	61	92	123	154	71	107	144	180
Gallons per minute	155	189	219	245	196	240	277	310	242	297	342	383	293	3[illegible]8	413	462
Horizontal distance thrown	10[illegible]	142	168	186	113	148	175	193	118	156	186	207	124	166	200	224
Vertical distance thrown	79	108	131	148	81	112	135	157	82	115	142	164	85	118	146	169

***For greater lengths of 2 1-2 hose the increased friction can readily be obtained by noting the differences between the above given "pressure at nozzle" and "pressure at pump or hydrant with 100 feet of hose." For instance, if it requires at hydrant or pump 8 pounds more pressure than it does at nozzle to overcome the friction when pumping through 100 feet of 2 1-2 inch hose (using 1-inch nozzle, with 40 pounds pressure at said nozzle); then it requires 16 pounds pressure to overcome the friction in forcing through 200 feet of same size hose.**

Insurance rates are governed by the efficiency of the plant in any town and a good showing of large mains has its effect. If a volume of water flowing through a two inch pipe had to flow in the same time through a one inch pipe the velocity would be increased four times, but the friction sixteen times. No mains should be less than six inches in a town and eight inches is much better if the cost can be afforded. The writer realizes how difficult it is for many small places with a limited bonding power to put in large mains and therefore can not urge the putting in of larger than six or eight inch pipes. It is sensible and economical, however, to have as much large diameter pipe as possible and to have very little three and four inch pipe.

It is a badly designed water works which has not a double circulation. Pipes should be run down cross streets often, to connect pipes on parallel streets, and whenever a pipe stops it should stop at a street and from the end a pipe should go through the cross street and connect the parallel pipe line. This helps protect the purity of the water by the avoidance of dead ends, lessens the evil effects of water ram, permits a better flow to points where needed in times of extraordinary draught and allows repairs to be made in districts of limited area without inconveniencing many patrons.

Nothing shows the amateur hand so quickly in a water works system as the presence of dead ends and the absence of a proper number of gates and valves. The proper number of gates and valves is not a difficult thing to determine. There should be a gate on every lead of pipe at all intersections, so that at a street crossing where four pipes come together there should be four gates, one at each property line. There should be a gate on every hydrant lead so the hydrants can be repaired without interfering with the working of the system. With a double circulation and plenty of gates, water can be turned on in one block at any time by the closing of two gates and repairs made anywhere in that block, the only inconvenience suffered being by those who are in the small district served by that pipe. This saves time and money.

It is well when water has to be pumped for supply that economy be in operation be carefully looked into. For example it is well to have the pressure for fire purposes as near one hundred pounds to the square inch as possible. For domestic use thirty-five to forty pounds will be ample.

There are some towns where the contract with the water company calls for a high pressure to be constantly maintained. Therefore water is pumped to a great height to reservoirs, or tanks, and the supply drawn from them. Much economy in operation can be secured by locating a tank where sufficient pressure can be secured for fire purposes and keeping that tank filled.

A tank at a lower elevation can be used for a constant supply or the pumps can be run continuously. When a fire occurs and the greater pressure is needed the high tank, or reservoir, can be brought into immediate service by gates, or valves automatically controlled.

There are today many devices on the market for controlling pressures. For example, a town may be located on a flat river bank close to a hill. On the hill the reservoir is located and after a while the residences go there. To make the pressure practically uniform all over the place several mains are used to supply the lower part, on one or two of which pressure regulators are placed. These regulators act by throttling the flow and thus keeping the pressure down to any desired point in the low lying district. When several hydrants are opened at one time and draw on the main the valve opens enough to let all the water through that is needed. This serves until valves or gates on the other mains are opened so that the whole lower system gets the increased pressure. It does no harm, however, to house connections, as the increased supply furnished is used immediately by the fire streams. The valves can be closed before the fire streams are shut off.

A good pressure in case of fire is needed, but it is hard on domestic plumbing to have a high pressure kept up. It is therefore best to so plan the system that a good enough pressure will be had all over town for domestic purposes with a reserve high pressure in case of fire. It means, of course, that all plumbing must be able to withstand the effects of the high pressure in case the fire streams cease using the extra supply before the pressure is reduced.

The question of material for pipes need only be briefly touched upon. Cast iron has been for years the standard material for piping systems and with the majority of engineers is a favorite. Cast iron pipes represent rather too much dead weight compared with their strength, as the best method of obtaining long service before destruction by rust is to make them thick. This to towns where

freight is an item is a great objection to their use. It is very hard to prevent incrustation in cast iron pipes and being, to a certain extent, brittle, they are in greater danger of breakage from "water ram" than wrought iron pipe. Cast iron pipe is usually in 12-foot lengths, measuring from mouth to mouth of the bells.

For small cities and towns the writer confesses to wrought iron and steel pipe being a favorite with him. When cast iron can be laid down at the trench for the same money he will take it. A difference, however, of 5 per cent in cost will decide him in favor of the other pipe.

Wrought iron pipe needs protective coatings more than cast iron to protect it from corrosion. It retains these protective coatings badly unless they are very carefully made and applied and then the life is as great as that of any pipe. It possesses greater strength in proportion to its weight than cast iron and a difference in cost in its favor is generally owing to freight rates. It is not troubled with incrustation to the extent that cast iron is and coming in longer sections than cast iron requires fewer joints, less lead and packing, less labor in laying and is cheaper to maintain. Lock joint, seamless, wrought iron pipe is superior to lap and riveted pipe owing to the interior smoothness enabling an even flow to be maintained.

Wooden pipe is advertised considerably. The writer has used it made of staves of California redwood and of staves made from Oregon fir. He has recommended its use in many places and believes it to be a good pipe when it can compete with cast iron pipe in price.

Several firms manufacture it in different parts of the United States, but in the West it is used more than elsewhere. It has a smoother surface than any other kind of pipe because of the few joints. The writer believes, however, that some of the theoretical efficiency is lost by the swelling of the wood.

Some of the pipe is banded with flat bands and this, in the writer's opinion, is not so good as where round bands are used. Some companies make the pipe in lengths and band it with galvanized steel wire wrapped spirally. Joints are made with sleeves of iron or steel, or what is better, by sleeves of wood wrapped with wire.

For pipe less than twelve inches in diameter it is customary to

have eight, ten or twelve foot lengths, made of staves and banded. For twelve inches and upward the pipe is built in the trench.

Some firms manufacture wooden pipe by boring holes through logs and banding them with metal. The writer has never known of such pipe being successful for a long time. The hard wood is cut out by the hole and only the sap wood is left.

It is well known that wood will not rot so long as it is saturated with water. Alternate wetting and drying rot wood. A properly constructed wooden pipe will last as long as the metal banding it. It is usual to galvanize the metal and then after the pipe is made, to coat the whole pipe and metal with asphalt.

Sewer pipe of vitrified clay is used in many places as a conduit where it has been found possible to lay it on an even grade where it will not be under pressure. It has been used in a very few places under a light pressure. It has not always proven a success, but when covered with a foot or two of earth to protect it there has been little or no trouble. Where used it has been in situations in which a ditch or wooden flume might ordinarily be used and is advantageous in being a closed conduit.

Concrete is a most excellent material for conduits flowing under little or no pressure. Reinforced concrete is rapidly coming to the front for aqueduct purposes and has been used under very great pressure.

Carrying capacities of aqueducts for water are reduced seriously by slime and other growths. Studies of well known aqueducts show that the carrying capacity of the Sudbury aqueduct has at times been reduced as much as 13½ per cent; the Cochituate aqueduct 11¾ per cent, and the Wachusett aqueduct from 10 to 11 per cent.

When vegetable growths appear in reservoirs, and bad smells and tastes are noticed, copper sulphate is used to remove the offensive conditions. The amount used varies from 1 in 1,000,000 to 1 in 7,000,000 parts by weight. That is, one pound of copper sulphate in one to seven million pounds of water.

The copper sulphate is put in bags containing 75 to 100 lbs. and the bags are towed, one at a time, from a boat. The boat is rowed around the reservoir in concentric courses 40 to 50 feet apart at such a rate as to completely cover same by the time the sulphate is all dissolved. A 75-pound bag will dissolve in about half an

hour. The advice of a competent chemist should be obtained before using this method.

Old-fashioned methods of thawing frozen water pipes by opening trenches and building fires have been superseded by electrical thawing. The following is the practice for house connections in Ottawa, Can.: Current is taken from the wires of the electric light company and reduced by transformers to about 25 volts. The charge is $1.25 per hour for current and apparatus. One wire is connected to the service in the house and the other to the stopcock box in the street, an adjoining service or the nearest street hydrant, the object being to have a connection on either side of the frozen section and as close as possible. The electrical current sometimes clears the pipe in thirty seconds, but if the service is long and frozen solid it varies from that to thirty minutes. Where couplings with a leather washer are used at the stopcock boxes the current will burn out the washer and cause a slight leak. Where the coupling used is of brass and lead the current causes no leak and no damage is occasioned the service, except in isolated and difficult cases where more than 25 volts are used.

Much valuable information on this subject with reports from many cities is to be found in a report compiled by George S. Hale, for the National Electric Light Association, and published by the association at New York.

SPECIFICATION FOR LAYING WATER PIPE.

(First, specify the hydrants, pipe, valves, etc., and all accessories and materials and labor.

Specify the doing of the work in full accordance with the plans and drawings forming a part of the specifications.

Second, specify all the items likely to complicate the opening of trenches in the streets.)

All parts liable to draw shall be firmly secured by straps and bolts. In addition to this a firm blocking shall be set behind all caps, curves, hydrants and branches, said blocking to be tightly wedged and have a large surface against the undisturbed earth.

When laid the spigots of the pipe shall be so adjusted that there shall be a uniform space all around and if any pipe does not allow sufficient space it shall be replaced by one of proper form and dimensions. The minimum dimensions of joints shall be as follows:

Size of Pipe.	Depth of Joint.	Space.
4″ to 6″	3″	0.4″
8″ to 14″	3.5″	0.4″
16″	4″	0.5″

The pipes shall lack one-quarter of an inch of being driven full into bells, and gaskets of clean, sound hemp yarn, braided or twisted and tightly driven, shall be used to pack the joints.

The lead shall be pure, soft lead of the best quality, suitable for caulking, and securing a tight and permanent joint.

Joints shall be first cleaned and wiped perfectly dry. The melting pot shall never be more than fifteen feet away from the joint to be poured, and the joint shall be run full at one pouring.

Competent, experienced mechanics must be employed to do the caulking. The caulking must be faithfully executed so the joint will be tight and secure without overstraining the metal in the bell of the pipe. After caulking the lead shall be flush with the face of the socket.

All pipes and casting shall be carefully cleaned before laying, and again after laying. Open ends shall be plugged when work is left at night or during a lay-off, at noon hour or other time. After removing plug, interior of pipe shall be inspected before commencing work. Care must at all times be exercised to prevent earth, sand, mud or rubbish from being left in pipes or castings.

Care should be taken to give the pipe a solid bearing throughout its entire length. If the earth excavated from the trench can be deposited firmly around and over the pipe to secure it from after settlement, it can be used and must be tamped and moistened as tamped until at least one foot in depth covers the pipe. One or more feet in length at each end of the pipe, depending upon the size, shall be left unfilled until the rest of the pipe has been so covered, to allow examination of the joint and for necessary recaulking in case the joint has been disturbed by the filling. The joints shall then be covered by filling and tamping in the same way. After the pipes have been covered with one foot of filling as specified, the remainder of the trench shall be filled in any practicable manner and so tamped or flooded that there will be no settlement of the street surface.

No stones or rock fragments shall be permitted in the filling within six inches of the pipe.

If the earth removed from the trench can not be replaced properly in the opinion of the engineer in charge the trench shall be filled under, around and for six inches on top with sand, thoroughly rammed and afterward compacted by flooding with water.

(NOTE—Here should follow specifications for restoring street surfaces.)

The specifications for sewer work should be consulted for information about excavating and backfilling, leaving in sheeting, etc.

PUMPING WATER.

Let L=lift in feet.
F=cubic feet per second
G=U. S. gallons per minute.
Q=millions of U. S. gallons per 24 hours.
HP=theoretical horse-power required.

$$\text{Then HP} = \frac{F \times L}{8.82}; \text{HP} = \frac{Q \times L}{5.7}; \text{HP} = \frac{G \times L}{4{,}000}$$

The friction losses must be found and the head to overcome them added to the "Lift in feet" in order to obtain the actual horsepower necessary.

The following table for use with centrifugal pumps is from the catalogue of manufacturers of such pumps.

Revolutions and Horse-Power Required to Elevate Water to Different Heights with Centrifugal Pumps.

No. Pump	Cap. Gals.	H. P. per Ft. Elev.	5 ft.	10 ft.	15 ft.	20 ft.	25 ft.	30 ft.	35 ft.	40 ft.	50 ft.	60 ft.
1½	70	.058	642	784	904	1010	1104	1193	1274	1352	1493	1622
1¾	90	.075	473	570	651	724	790	850	906	959	1058	1147
2	120	.10	364	443	511	570	623	672	718	762	840	913
2½	185	.15	389	448	500	547	590	630	667	703	770	830
3	265	.22	286	359	419	475	517	559	599	636	704	766
3½	360	.26	352	413	455	513	555	595	632	667	733	793
4	470	.30	324	390	445	493	539	580	618	654	721	771
5	735	.45	311	368	418	462	502	532	574	606	666	722
6	1060	.59	247	300	345	385	421	453	484	513	566	615
8	2000	1.00	247	300	345	385	421	453	484	513	566	615
10	3000	1.52	160	226	278	320	358	392	424	456	506	555
12	4300	2.00	133	188	230	266	298	326	352	376	421	461
15	7000	3.50	151	213	261	301	337	369	399	426	477	522
18	10000	4.50	151	213	2[illegible]1	301	337	369	299	426	477	522

MEASURING STREAMS.

A rough and ready method used in small streams, or rather to gauge streams flowing from springs, is to measure with cans. Put a dam of some sort across the little stream and place in the top a small V flume or pipe at such a grade that the water will only rise to a certain height behind the dam. Have two five-gallon coal oil cans with handles. Place one under the flume or pipe and as fast as it fills remove it and substitute the other. After each has been filled and emptied five times there has been a total flow of fifty gallons. A careful timing of the operation gives closely the flow in gallons per minute. Needless to say, this is only useful in very small streams.

For something more definite place across the stream a board with the top perfectly level. The edge should be beveled on the lower side so the upper edge will be sharp. Square ends should be placed on the board so that the water flowing over will have a certain width and will flow quietly. A few feet back from the board (weir) drive a peg into the stream and set it by means of a level so the top will be exactly the height of the edge over which the water flows. When the stake is set measure the depth of water over it, which gives the weir depth. The weir table here

Giving cubic feet of Water per minute, that will flow over a Weir one inch wide and up to 25 inches deep.

Inch.		⅛	¼	⅜	½	⅝	¾	⅞
1	.40	.47	.55	.65	.74	.83	.93	1.03
2	1.14	1.24	1.36	1.47	1.59	1.71	1.83	1.96
3	2.09	2.23	2.36	2.50	2.63	2.78	2.92	3.07
4	3.22	3.37	3.52	3.68	3.83	3.99	4.16	4.32
5	4.50	4.67	4.84	5.01	5.18	5.36	5.54	5.72
6	5.90	6.09	6.28	6.47	6.65	6.85	7.05	7.25
7	7.44	7.64	7.84	8.05	8.25	8.45	8.66	8.86
8	9.10	9.31	9.52	9.74	9.96	10.18	10.40	10.62
9	10.86	11.08	11.31	11.54	11.77	12.00	12.23	12.47
10	12.71	12.95	13.19	13.43	13.67	13.93	14.16	14.42
11	14.67	14.92	15.18	15.43	15.67	15.96	16.20	16.46
12	16.73	16.99	17.26	17.52	17.78	18.05	18.32	18.58
13	18.87	19.14	19.42	19.69	19.97	20.24	20.52	20.80
14	21.09	21.37	21.65	21.94	22.22	22.51	22.79	23.08
15	23.38	23.67	23.97	24.26	24.56	24.86	25.16	25.46
16	25.76	26.06	26.36	26.66	26.97	27.27	27.58	27.89
17	28.20	28.51	28.82	29.14	29.45	29.76	30.08	30.39
18	30.70	31.02	31.34	31.66	31.98	32.31	32.63	32.96
19	33.29	33.61	33.94	34.27	34.60	34.94	35.27	35.60
20	35.94	36.27	36.60	36.94	37.28	37.62	37.96	38.31
21	38.65	39.00	39.34	39.69	40.04	40.39	40.73	41.09
22	41.43	41.78	42.13	42.49	42.84	43.20	43.56	43.92
23	44.28	44.64	45.00	45.38	45.71	46.08	46.43	46.81
24	47.18	47.55	47.91	48.28	48.65	49.02	49.39	49.76

given can then be used to ascertain the amount of water flowing in the stream.

The following weir formulas are standard. The Francis formula for discharge in cubic feet per second for weir in thin plate and without end contraction is:

$$Q = 3.33\ L\ H^{\frac{3}{2}}$$

where Q is the quantity

L is the length of weir in feet.

H is the head over weir in feet.

The Cippoletti formula is the same with a constant of 3.367 instead of 3.33.

The Smith-Francis formula is as follows for cubic feet per second:

$$Q = 3.29\left(L - \frac{H}{0.10}\right)H^{\frac{3}{2}}$$

and as follows when the discharge is in gallons per minute:

L is length of weir in inches, and

h is head of water over weir in inches.

$$Q = 2.97\left(L - \frac{h}{0.10}\right)h^{\frac{3}{2}}$$

When streams are too large to measure with a weir, stations are measured 100 feet or more in length along the side and soundings taken across the stream at these points to obtain the cross section. Floats, so weighted that they will be in the center of average velocity, are timed as they pass over a given course. Having the average cross section of the stream and the average velocity of the floats over the section on which this average cross section was taken, the computation of the flow is readily performed.

The following is an abridgement of an article by Ernest W. Schoder, in The Engineering Record, September 3, 1904:

This form of diagram for the solution of the usually recurring problems in pipe hydraulics has the merits of dependence on a definite basis, simplicity, compactness and quite sufficient accuracy. It is based on diagrams by Professor Church of Cornell University.

In the accompanying diagram the entire range of ordinary practice is included. Enough lines are drawn so that interpolation will give rather more than justifiable accuracy for all purposes of design.

It is drawn upon logarithmic cross section paper, which is

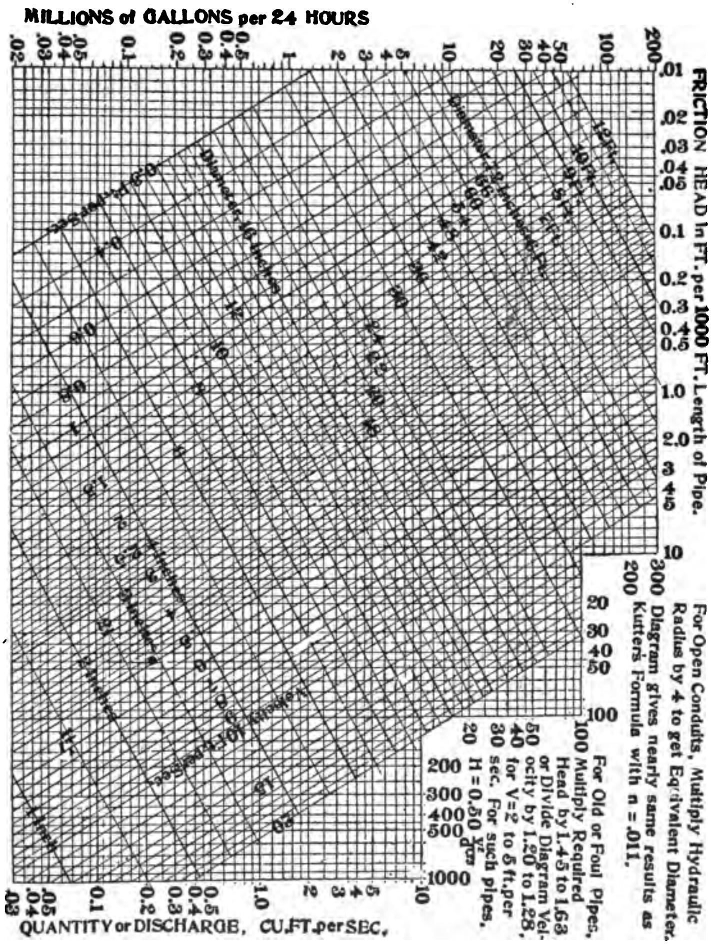


DIAGRAM FOR FLOW OF WATER IN CLEAN CAST IRON OR WROUGHT IRON PIPES. **Based on the Formula, H. in Ft. per 1000 Ft., = 0.38 $\frac{v^{1.86}}{d^{1.25}}$.**

(Trans. Am. Soc. C. E., Vol. LI.)

ruled like a common slide rule, therefore a cross section line marked with a certain value represents actually the logarithm of that value. The abscissas represent logarithms of values of the hydraulic slope, or, as on the diagram, a multiple of the same, i. e., "friction head," in feet per thousand feet length of pipe.

Table Giving Weights and Thicknesses of Cast Iron Pipe.

Size of Pipe	Light Weight			Standard Weight			Heavy Weight		
	Weight per Foot	Weight per Length	Metal	Weight per Foot	Weight per Length	Metal	Weight per Foot	Weight per Length	Metal
3	15	180	13/32	17	204	15/32	19	228	1/2
4	20	240	[illegible]	22	264	15/32	24	288	1/2
6	30	360	7/16	33	396	1/2	35	420	[illegible]
8	40	480	[illegible]	42	504	[illegible]	50	600	[illegible]
10	55	660	[illegible]	60	720	[illegible]	65	780	[illegible]
12	70	840	1/2	75	900	[illegible]	85	1020	[illegible]
14	90	1080	9/16	100	1200	[illegible]	117	1404	[illegible]
16	100	1200	[illegible]	125	1500	[illegible]	150	1800	[illegible]
18	135	1622	[illegible]	167	2004	[illegible]	200	2400	[illegible]
20	150	1800	[illegible]	200	2400	[illegible]	225	2700	1
24	200	2400	[illegible]	250	3000	1	300	3600	1 3/16
30	250	3000	[illegible]	334	4008	1 3/16	417	5004	1 1/4
36	334	4008	7/8	450	5400	1 1/8	500	6000	1 3/8
42	450	5400	1	600	7200	1 3/8	750	9000	1 3/4
48	600	7200	1 1/8	725	8700	1 7/16	850	10200	1 5/8
60	900	10800	1 3/8	1075	12900	1 5/8	1250	15000	1 7/8
72	1340	16080	1 5/8	1560	18720	1 7/8	1750	21200	2 1/8

(After describing the formulas and the manner in which the diagram is constructed the following directions for use are given.)

In use, if the head and diameter be given, the intersection of the lines for the given values will give the velocity and discharge. The latter can be read in cubic feet per second on the right of the diagram, or in millions of gallons per day on the left, as may be desired. If the discharges only be given, the required heads and the corresponding velocities for different diameters of pipe can be read off by following along the horizontal line for the given discharge, and noting intersections. If the diameter only be fixed, the required heads for various discharges can be found by following along the line for the given diameter.

For old pipes, not too badly fouled or too heavily tuberculated (with sufficient exactness in ordinary cases) increase the diagram

head one-half or decrease the diagram discharge and velocity by one-quarter.

In general, for pipes in good condition, the diagram may be relied on to give results rather on the safe side than otherwise.

Height of Chimneys in Feet—Commercial Horse Power

Diam. in In.	50	60	70	80	90	100	110	125	150	175	200
18	23	25	27	...	....	....	....	.....	.....	.....	....
21	35	38	41	....	....	....	....	.....	.....	.....	....
24	49	54	58	62	....	....	....	.....	.....	.....	....
27	65	72	78	83	....	....	....	.....	.....	.....	....
30	84	92	100	107	113	....	....	.....	.....	.....	....
33	....	115	125	133	141	....	....	.....	.....	.....	....
36	....	141	152	163	173	182	....	.....	.....	.....	....
39	....	....	183	196	208	219	....	.....	.....	.....	....
42	....	....	216	231	245	258	271	294	318	341	364
48	....	....	....	311	330	348	365	389	428	459	491
54	....	....	....	363	427	449	472	503	551	594	635
60	....	....	....	505	539	565	593	632	692	748	797
66	....	....	....	....	658	694	728	776	849	918	981
72	....	....	....	....	792	835	876	934	1023	1105	1181
78	....	....	....	....	....	995	1038	1107	1212	1310	1400
84	....	....	....	....	....	1163	1214	1294	1418	1531	1637
90	....	....	....	....	....	1344	1415	1496	1639	1770	1893
96	....	....	....	....	....	1537	1616	1720	1876	2027	2167
108	....	....	....	....	....	....	....	....	2290	2470	2637
120	....	....	....	....	....	....	....	....	2827	3049	3255

Reduction of Chimney Draft by Long Flues

Total length of flues in feet..	50	100	200	400	600	800	1000	2000
Chimney draft in per cent....	100	93	79	66	58	52	48	35

Examples.—1. Given a head of 100 feet in five miles, required the discharge for various diameters of pipe. The head per 1,000 feet is here 3.78 feet. Following down the space in which this value occurs, we find that a 48-inch pipe will give 109 cubic feet per second (read on the right) or 70,000,000 gallons per day (read on left). So, also, pipes of 36 inches, 24 inches, 16 inches, 8 inches diameter will discharge, respectively, 51, 17, 5.8, 0.91 cubic feet per second, or 33,000,000, 11,000,000, 3,750,000, 590,000 gallons per day.

2. Given a discharge of 10,000,000 gallons per day, required the necessary head for different diameters of pipe. Following

horizontally along the line for which this discharge is marked at the left of the diagram, we find that a 36-inch pipe with a head of 0.43 feet per 1,000 feet will answer. Also pipes of diameters 30 inches and 24 inches will give the required discharge if the heads be, respectively, 1.02 and 3.2 feet per 1,000 feet.

3. It is desired to limit the velocity in a cast-iron pipe line supplying power to 2.5 feet per second. The quantity of water required is 12 cubic feet per second. What size of pipe is necessary and what loss of head is involved? Noting the intersection of the line for 2.5 feet per second velocity with the horizontal line for 12 cubic feet per second, we see that a 30-inch pipe losing a head of 0.66 feet per 1,000 feet will answer the requirements.

In the chapter on water supply a table is given of water pressures as reduced by hose. The following table is of the same nature, but deals with single and siamesed connections, such as are used in buildings for fire protection:

TABLE OF REQUIRED HYDRANT PRESSURES (POUNDS).

Hose diameter.	2½″		3″		3½″	
Hose lines,	Single	Siamesed	Single	Siamesed	Single	Siamesed
Smooth bore nozzle,	1¼″	2″	1¼″	2″	1¼″	2″
Length of hose line........100′	121	139	92	101	84.5	88
" ....150′	139	170	99.5	113	87.5	93.5
" ....200′	158	201	107	125	91.	99.
" ....250′	176.5	232	114.5	137	94.5	104.5
" ....300′	195	263	122	149	98	110
" ....400′	232	325	137	173	105	121

NOTE.—From data derived from experiments by John R. Freeman (Transactions American Society of Civil Engineers, November, 1899)

The loss of pressure in the 3-inch and 3½-inch hose probably represents unusually good conditions, and in practice may somewhat exceed the above figures. Not included in the above are losses not exceeding 5 lbs. incurred in a siamese connection.

The table of Fire Stream Data is intended to be used in connection with calculations for heights of towers when such a system of supply is contemplated.

The other tables here presented may be useful in connection with water works design or extension.

With a joint about 2½ inches deep the weight of lead per running foot is equal to about one-sixth of the diameter of the pipe in inches. If a 4-inch joint is used, the weight of the lead per running foot is equal to about one-fourth of the diameter in inches.

Fire Stream Data for 1-Inch Smooth Nozzle

This Table also Serves for 1⅛-Inch Ring Nozzle

Indicated Pressure Pounds	Best Fire Jet		Gallons per Minute	Height of Tower required to maintain Fire Streams as shown in columns 2 and 3 through 2½-inch Rubber Hose Lines mentioned					
	Height Feet	Reach Feet		50 Feet	100 Feet	200 Feet	300 Feet	400 Feet	500 Feet
25	43	42	147	67	71	82	94	106	117
30	51	47	161	77	84	99	113	126	140
35	58	51	174	92	102	117	131	147	163
40	64	55	186	106	115	133	151	168	186
45	69	58	198	119	129	149	170	191	209
50	73	61	208	131	142	165	188	211	234
55	76	64	218	145	158	181	207	232	257
60	79	67	228	158	172	200	226	253	280
65	82	70	237	172	186	216	246	273	303
70	85	72	246	184	200	232	264	294	327
75	87	74	255	197	216	248	282	317	349
80	89	76	263	211	230	264	300	338	372
85	91	78	274	226	243	282	319	359	398
90	92	80	279	237	257	298	338	379	420
95	94	82	287	250	271	314	359	400	444
100	96	83	295	264	287	331	377	420	467

Fire Stream Data for 1⅛-Inch Smooth Nozzle

Indicated Pressure Pounds at Nozzle	Best Fire Jet		Gallons per Minute	Height of Tower required to maintain Fire Streams as shown in columns 2 and 3 through 2½-inch Rubber Hose Lines mentioned					
	Height Feet	Reach Feet		50 Feet	100 Feet	200 Feet	300 Feet	400 Feet	500 Feet
25	44	44	188	72	80	100	119	237	156
30	52	50	206	86	96	121	142	165	186
35	59	54	222	100	112	140	165	190	218
40	65	59	238	116	128	161	188	218	248
45	70	63	252	130	144	180	204	246	278
50	75	66	266	144	160	201	227	274	310
55	80	69	279	158	176	222	250	302	340
60	83	72	291	172	192	241	273	327	370
65	86	75	303	188	208	262	296	355	402
70	88	77	314	202	224	281	322	383	432
75	90	79	325	216	240	302	345	411	464
80	92	81	336	230	256	323	368	436	494
85	94	83	346	246	272	342	391	464	524
90	96	85	356	260	288	363	414	492	556
95	98	87	366	274	304	382	439	520	586
100	99	89	376	288	320	403	462	548	608

Friction of Water in Pipes

Friction loss in pounds pressure per square inch for each 100 feet of length in different size clean iron pipe, discharging given quantities of water per minute.

Gallons per Minute	Size of Pipe—Inside Diameter.										
	1 in.	1¼ in.	2 in.	2½ in.	3 in.	4 in.	5 in.	6 in.	8 in.	10 in.	12 in.
5	0.84	0.12	0.03								
10	3.16	0.47	0.12	0.03							
15	6.96	0.97	0.27	0.08							
20	12.3	1.66	0.42	0.13	0.03						
25	19.0	2.62	0.67	0.21	0.10						
30	27.5	3.75	0.91	0.30	0.12	0.03					
35	37.0	5.05	1.26	0.42	0.14	0.05					
40	48.0	6.52	1.60	0.51	0.17						
45		8.15	2.01	0.63	0.27	0.07					
50		10.0	2.44	0.81	0.35	0.09	0.03				
75		22.4	5.32	1.80	0.74	0.21	0.06	0.03			
100		39.0	9.46	3.30	1.31	0.33	0.12	0.05			
125			14.9	4.89	1.99	0.51	0.17	0.07			
150			21.2	7.0	2.85	0.69	0.25	0.10	0.02		
175			28.1	9.46	3.85	0.95	0.34	0.14	0.03		
200			37.5	12.47	5.02	1.22	0.42	0.17	0.05	0.01	
250				19.66	7.76	1.89	0.65	0.26	0.07	0.03	0.01
300				28.06	11.02	2.66	0.93	0.37	0.09	0.04	

Gallons	3 in.	4 in.	5 in.	6 in.	8 in.	10 in.	12 in.	14 in.	16 in.	18 in.	20 in.
350	15.2	3.65	1.28	0.50	0.12	0.05	0.02				
400	19.5	4.73	1.68	0.65	0.16	0.06					
450	25.0	6.01	2.10	0.81	0.20	0.07	0.08				
500	30.8	7.43	2.70	0.96	0.25	0.09	0.04	0.017	0.009	0.005	
600		10.6	3.45	1.72	0.348	0.13	0.05	0.024			
750			5.40	2.21	0.58	0.18	0.08	0.038			
1000			9.60	3.88	0.94	0.32	0.13	0.062	0.036	0.02	
1250					1.46	0.49	0.20				
1500					2.09	0.70	0.29	0.185	0.071		
1750						0.95	0.38				
2000						1.28	0.49	0.234	0.123		
2500							0.77	0.362	0.188	0.107	
3000							1.11	0.515	0.267	0.15	0.09
3500								0.697	0.365	0.204	0.124
4000								0.91	0.47	0.264	0.158
4500									0.593	0.33	0.20
5000									0.78	0.41	0.244

Contents in Cubic feet, U. S. gallons and weight of water per foot length for pipe of various diameters, also area in square feet and inches, and circumference in inches.

Diameter of Pipe in inches.	Area in sq. feet or contents in Cubic feet per foot of length.	Contents in U.S. gallons per foot length.	Weight of water in one foot length, in lbs.	Area in sq. in.	Circumference in inches.
1	.0055	.0408	.34	.78	3.14
2	.0218	.1632	1.36	3.14	6.28
3	.0491	.3672	3.06	7.06	9.42
4	.0873	.6528	5.44	12.56	12.56
5	.1364	1.020	8.51	19.63	15.70
6	.1963	1.469	12.25	28.27	18.85
7	.2673	1.999	16.68	38.48	21.99
8	.3491	2.611	21.79	50.26	25.13
9	.4418	3.305	27.57	63.61	28.27
10	.5454	4.08	34.04	78.54	31.41
11	.66	4.937	41.19	95.03	34.55
12	.7854	5.875	49.02	113.10	37.69
13	.9218	6.895	57.54	132.73	40.84
14	1.069	7.997	66.73	153.94	43.98
15	1.227	9.180	76.60	176.71	47.12
16	1.396	10.44	87.16	201.06	50.26
18	1.768	13.22	110.31	254.47	56 54
20	2.182	16.32	136.19	314.16	62.83
22	2.640	19.75	164.79	380.13	69.11
24	3.142	23.50	196.11	452.39	75.39
26	3.687	27.58	230.16	530.93	81.68
28	4.276	31.99	266.93	615.75	87.96
30	4.909	36.72	306.42	706.86	94.24
32	5.585	41.78	348.64	804.25	100.53
34	6.305	47.16	393.59	907.92	106.81
36	7.069	52.88	441.25	1017.9	113.09
38	7.876	58.92	491.64	1134.1	119.38
40	8.727	65.28	544.76	1256.6	125.66
42	9.621	71.97	600.59	1385.4	131.94
44	10.559	78.99	659.16	1520.5	138.23
46	11.541	86.33	720.44	1661.9	144.51
48	12.566	94.00	784.45	1809.6	150.79

Number of Gallons in Round Cisterns and Tanks.

Depth in Feet	DIAMETER IN FEET														
	5	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24
5	735	1,060	1,440	1,875	2,380	2,925	3,550	4,237	4,960	5,765	6,698	7,520	9,516	11,750	14,215	16,918
6	881	1,270	1,728	2,250	2,855	3,510	4,260	5,084	5,952	6,918	8,038	9,024	11,419	14,100	17,059	20,302
7	1,028	1,480	2,016	2,625	3,330	4,095	4,970	5,931	6,944	8,071	9,378	10,528	13,322	16,450	19,902	23,680
8	1,175	1,690	2,304	3,000	3,805	4,680	5,680	6,778	7,936	9,224	10,718	12,032	15,225	18,800	22,745	27,070
9	1,322	1,900	2,592	3,375	4,280	5,265	6,390	7,625	8,928	10,377	12,058	13,536	17,128	21,150	25,588	30,454
10	1,469	2,110	2,880	3,750	4,755	5,850	7,100	8,472	9,920	11,530	13,398	15,040	19,031	23,500	28,431	33,838
11	1,616	2,320	3,168	4,125	5,250	6,435	7,810	9,319	10,913	12,683	14,738	16,544	20,934	25,850	31,274	37,222
12	1,762	2,530	3,456	4,500	5,705	7,020	8,520	10,166	11,904	13,836	16,078	18,048	22,837	28,200	34,117	40,606
13	1,909	2,740	3,744	4,875	6,180	7,605	9,230	11,013	12,896	14,989	17,418	19,552	24,740	30,550	36,960	43,990
14	2,056	2,950	4,032	5,250	6,655	8,190	9,940	11,860	13,888	16,142	18,758	21,056	26,643	32,900	39,803	47,87[illegible]
15	2,203	3,160	4,320	5,625	7,130	8,775	10,650	12,707	14,880	17,296	20,098	22,560	28,546	35,250	42,646	50,758
16	2,356	3,370	4,608	6,000	7,605	9,360	11,360	13,554	15,872	18,448	21,438	24,064	30,449	37,600	45,489	54,142
17	2,497	3,580	4,896	6,375	8,080	9,945	12,070	14,401	16,864	19,601	22,778	25,568	32,352	39,950	48,332	57,520
18	2,644	3,790	5,184	6,750	8,535	10,530	12,780	15,248	17,856	20,754	24,118	27,072	34,255	42,300	51,175	60,910
19	2,791	4,000	5,472	7,125	9,010	11,115	13,490	16,095	18,848	21,907	25,458	28,576	36,158	44,650	54,018	64,294
20	2,938	4,210	5,760	7,500	9,490	11,700	14,200	16,942	19,840	23,060	26,798	30,080	38,062	47,000	56,861	67,678

Table Showing Flow of Water per Second through Clean Iron Pipes.

Fall in feet per 100 ft. of pipe	DIAMETERS.								
	1 in. cu. ft.	2 in. cu. ft.	3 in. cu. ft.	4 in. cu. ft.	6 in. cu. ft.	8 in. cu. ft.	10 in. cu. ft.	11 in. cu. ft	12 in. cu. ft.
.10	......	......	......	......	......	......	......	......	1.265
.12	......	......	......	......	......	......	.878	1.120	1.402
.14	......	......	......	......	......	......	.960	1.221	1.489
.16	......	......	......	......	......	.573	1.047	1.320	1.634
.18	......	......	......	......	......	.611	1.110	1.394	1.728
.20	......	......	......	......	.298	.639	1.194	1.490	1.846
.22	......	......	......	......	.314	.659	1.265	1.580	1.940
.24	......	......	......	......	.330	.703	1.325	1.653	2.026
.26	......	......	......	.1235	.346	.737	1.377	1.722	2.117
.28	......	......	......	.1298	.359	.768	1.423	1.788	2.207
.30	......	......	.0630	.1336	.377	.808	1.470	1.854	2.297
.35	......	......	.0692	.1465	.395	.876	1.587	1.996	2.466
.40	......	.02584	.0749	.1562	.444	.931	1.683	2.136	2.662
.50	......	.02924	.0839	.1771	.496	1.046	1.865	2.397	3.020
.60	......	.03274	.0915	.1923	.548	1.575	2.059	2.636	3.310
.70	......	.03492	.0992	.2146	.589	1.262	2.222	2.858	3.601
.80	.00567	.03776	.1060	.2339	.631	1.344	2.383	3.062	3.856
.90	.00617	.04061	.1119	.2460	.672	1.424	2.514	3.232	4.072
1.00	.00677	.04321	.1190	.2582	.721	1.496	2.662	3.419	4.305
1.20	.00781	.04843	.1313	.2893	.784	1.644	2.932	3.760	4.728
1.40	.00841	.05150	.1413	.3036	.858	1.782	3.210	4.016	5.094
1.60	.00886	.05456	.1507	.3237	.922	1.916	3.450	4.390	5.482
1.80	.00961	.05740	.1590	.3412	.975	2.033	3.679	4.679	5.839
2.00	.00990	.06111	.1717	.3607	1.022	2.155	3.856	5.251	6.160
3.00	.01245	.07399	.2081	.4503	1.263	2.667	4.762	6.086	7.630
4.00	.01492	.08734	.2469	.5331	1.484	3.145	5.563	7.022	8.860
5.00	.01666	.1095	.2785	.5954	1.665	3.513	6.704	8.244	9.967
6.00	.01857	.1200	.3049	.6390	1.929	3.847	......	......	......
7.00	.01988	.1288	.3331	.6967	1.976	4.196	......	......	......
8.00	.02141	.1375	.3559	.7506	2.144	......	......	......	......
9.00	.02283	.1442	.3816	.7960	2.274	......	......	......	......
10.00	.02424	.1523	.4043	.9464	2.399	......	......	......	......
12.00	.02676	.1634	.4440	.9270	......	......	......	......	......
14.00	.02890	.1748	.4977	1.0060	......	......	......	......	......
15.98	.03081	.1856	.5131	1.0810	......	......	......	......	......
18.00	.03276	.1955	.5436	......	......	......	......	......	......
20.00	.03458	.2047	.5832	......	......	......	......	......	......
25.00	.03897	.2276	.6523	......	......	......	......	......	......
30.00	.04316	.2483	......	......	......	......	......	......	......
40.00	.04987	.2833	......	......	......	......	......	......	......
50.00	.05648	......	......	......	......	......	......	......	......
60.00	.06320	......	......	......	......	......	......	......	......
70.00	.06943	......	......	......	......	......	......	......	......

To find the velocity in feet per second necessary to carry a given quantity of water in a pipe of given diameter, divide the quantity in cubic feet per second by the area of the pipe in square feet; the quotient will give the velocity.

Table Showing Flow of Water per Second through Clean Iron Pipes.

Fall in feet per 100 feet of pipe	DIAMETER.											
	14 in. cu. ft.	15 in. cu. ft.	16 in. cu. ft.	18 in. cu. ft.	20 in. cu. ft.	22 in. cu. ft.	24 in. cu. ft.	26 in. cu. ft.	30 in. cu. ft.	36 in. cu. ft.	40 in. cu. ft.	48 in. cu. ft.
.02	.....	.....	.....	.....	.....	.....	.....	.....	.....	10.29	13.88	22.98
.03	.....	.....	.....	.....	.....	.....	.....	.....	7.78	12.70	17.00	27.89
.04	.....	.....	.....	.....	.....	.....	.....	.....	8.99	14.56	19.68	32.93
.05	.....	.....	.....	.....	.....	.....	.....	7.48	10.24	16.35	22.08	37.00
.06	.....	.....	.....	.....	3.61	4.61	6.10	7.61	10.97	18.02	24.43	40.21
.07	.....	.....	2.25	3.10	4.07	5.25	6.64	8.27	11.90	19.76	26 27	43.67
.08	1.71	2.05	2.43	3.27	4.35	5.62	7 13	8 70	12.84	20.85	28.14	46.81
.09	1.88	2.19	2.59	3.49	4.68	6.01	7.56	9.36	13.48	22.30	29.80	49.06
.10	1.91	2.30	2.72	3.66	4.92	6.32	7.96	9.81	14.21	23.47	31.46	52.15
.11	2.02	2.43	2.88	3.88	5.15	6.62	8.34	10.44	15.05	24.91	33.25	54.95
.12	2.11	2.54	3.02	4.06	5.40	6.94	8.75	10.87	15.81	26.12	34.68	57.36
.13	2.18	2.65	3.18	4.23	5.62	7.24	9.14	11.41	16.47	27.20	36.21	60.07
.14	2.27	2 75	3.28	4.40	5.82	7.51	9.47	11.80	17.18	28.24	37.57	62.02
.15	2.35	2.84	3.39	4.61	6.05	7.78	9.80	12.26	17.94	29.19	39.18	64.47
.16	2.44	2.94	3.49	4.75	6 27	8 03	10 13	12.70	18.58	30.29	40.54	66.53
.17	2.54	2.98	3.62	4.90	6.48	8.36	10.57	13.13	19.21	31.42	41.88	68.50
.18	2 59	3.11	3.69	5.03	6.65	8.55	10.77	13.46	19.66	32.48	43.07	70.62
.19	2.67	3.21	3.81	5.17	6.92	8.85	11.10	13.84	20.32	33.40	44.28	72.75
.20	2.72	3.29	3.92	5.30	7.05	9.07	11.43	14.23	20.79	34.49	45.20	74.44
.22	2.88	3.47	4.12	5.63	7.42	9.55	12.05	14.98	21.80	36.15	48.12	78.29
.24	3.02	3.63	4.32	5.87	7.79	10.01	12.61	15.69	22.83	37.74	50.48	81.68
.26	3.15	3.79	4.51	6.18	8.14	10.48	13.23	16.42	23.93	39.40	52.67	85.20
.28	3.29	3.95	4.68	6.38	8.48	10.91	13.79	17.07	24.86	40.86	55.04	88.46
.30	3.42	4.11	4.87	6.64	8.77	11.29	14.25	17.75	25.87	42.28	56.33	91.73
.35	3.62	4.46	5.31	7.17	9.49	12.25	15.50	19.25	27.96	45.95	61.09	100.40
.40	3.99	4.78	5 67	7.65	10.16	13.12	16.62	20.62	29.84	48.83	65.41	105.89
.50	4.46	5.37	6.39	8 66	11.43	14.78	18.71	23.13	33.56	54.89	73.09	119.34
.60	4.91	5.91	7.02	9.54	12.59	16.20	20.42	25.30	36.79	59.95	80.32	130.88
.70	5.37	6.45	7.66	10 33	13.66	17.53	22.05	27.12	39.66	65.17	86.70	148.09
.80	5.77	6.90	8.16	11.09	14.66	18.78	23.61	29.20	42.39	69.80	92.58	153.49
.90	6.11	7.31	8.64	11.71	15.54	19.93	25.07	31.00	45.23	74.33	98.00	.....
1.00	6.44	7.70	9.10	12.37	16.47	21.06	26.42	32.73	47.71	78.46	103.99	.....
1.20	7.00	8.39	9.95	13.65	17.99	23.07	29.03	36.18	52.91	82.84	.....	.....
1.40	7.60	9.15	10.87	14.75	19.49	24.68	31.49	39.31	57.65	.....	.....	.....
1.60	8.17	9.81	11.63	15.84	21.03	26.97	33.90	42.35	.....	.....	.....	.....
1.80	8.93	10.47	12.43	16.90	22.45	29.70	36.18	44.10	.....	.....	.....	.....
2.00	9.26	11.09	13.14	17.85	23.56	31.15	38.45	.....	.....	.....	.....	.....
3.00	11.39	13.66	16.17	21.86	28.86	.....	.....	.....	.....	.....	.....	.....
4.00	13.22	15.84	18.77	.....	.....	.....	.....	.....	.....	.....	.....	.....

To find the area of a required pipe, the quantity and velocity being given, divide the quantity in a stated time by the velocity in the same period; the quotient will be the required area, from which the diameter may readily be calculated.

PRESSURE OF WATER.

Head in Feet.	Pressure in Lbs. per Sq. Inch.	Head in Feet.	Pressure in Lbs. per Sq. Inch.	Head in Feet.	Pressure in Lbs. per Sq. Inch.	Head in Feet.	Pressure in Lbs. per Sq. Inch.	Head in Feet.	Pressure in Lbs. per Sq. Inch.	Head in Feet.	Pressure in Lbs. per Sq. Inch.
1	0.4	51	22.1	101	43.7	151	65.4	201	87.1	251	108.7
2	0.9	52	22.5	102	44.2	152	65.8	202	87.5	252	109.2
3	1.3	53	22.9	103	44.6	153	66.3	203	87.9	253	109.6
4	1.7	54	23.4	104	45.0	154	66.7	204	88.4	254	110.0
5	2.2	55	23.8	105	45.5	155	67.1	205	88.8	255	110.5
6	2.6	56	24.3	106	45.9	156	67.6	206	89.2	256	110.9
7	3.0	57	24.7	107	46.3	157	68.0	207	89.7	257	111.3
8	3.5	58	25.1	108	46.8	158	68.4	208	90.1	258	111.8
9	3.9	59	25.5	109	47.2	159	68.9	209	90.5	259	112.2
10	4.3	60	26.0	110	47.6	160	69.3	210	91.0	260	112.6
11	4.8	61	26.4	111	48.1	161	69.7	211	91.4	261	113.1
12	5.2	62	26.8	112	48.5	162	70.2	212	91.8	262	113.5
13	5.6	63	27.3	113	48.9	163	70.6	213	92.3	263	113.9
14	6.1	64	27.7	114	49.4	164	71.0	214	92.7	264	114.4
15	6.5	65	28.1	115	49.8	165	71.5	215	93.1	265	114.8
16	6.9	66	28.6	116	50.2	166	71.9	216	93.6	266	115.2
17	7.4	67	29.0	117	50.7	167	72.3	217	94.0	267	115.7
18	7.8	68	29.4	118	51.1	168	72.8	218	94.4	268	116.1
19	8.2	69	29.9	119	51.5	169	73.2	219	94.9	269	116.5
20	8.7	70	30.3	120	52.0	170	73.6	220	95.3	270	117.0
21	9.1	71	30.7	121	52.4	171	74.1	221	95.7	271	117.4
22	9.5	72	31.2	122	52.8	172	74.5	222	96.2	272	117.8
23	10.0	73	31.6	123	53.3	173	74.9	223	96.6	273	118.3
24	10.4	74	32.0	124	53.7	174	75.4	224	97.0	274	118.7
25	10.8	75	32.5	125	54.1	175	75.8	225	97.5	275	119.1
26	11.3	76	32.9	126	54.6	176	76.2	226	97.9	276	119.6
27	11.7	77	33.3	127	55.0	177	76.7	227	98.3	277	120.0
28	12.1	78	33.8	128	55.4	178	77.1	228	98.8	278	120.4
29	12.5	79	34.2	129	55.9	179	77.5	229	99.2	279	120.8
30	13.0	80	34.6	130	56.3	180	78.0	230	99.6	280	121.3
31	13.4	81	35.1	131	56.7	181	78.4	231	100.1	281	121.7
32	13.9	82	35.5	132	57.2	182	78.8	232	100.5	282	122.1
33	14.3	83	35.9	133	57.6	183	79.3	233	100.9	283	122.6
34	14.7	84	36.4	134	58.0	184	79.7	234	101.4	284	123.0
35	15.2	85	36.8	135	58.5	185	80.1	235	101.8	285	123.4
36	15.6	86	37.2	136	58.9	186	80.6	236	102.2	286	123.9
37	16.0	87	37.7	137	59.3	187	81.0	237	102.7	287	124.3
38	16.5	88	38.1	138	59.8	188	81.4	238	103.1	288	124.7
39	16.9	89	38.5	139	60.2	189	81.9	239	103.5	289	125.2
40	17.3	90	39.0	140	60.6	190	82.3	240	104.0	290	125.6
41	17.7	91	39.4	141	61.1	191	82.7	241	104.4	291	126.0
42	18.2	92	39.8	142	61.5	192	83.2	242	104.8	292	126.5
43	18.6	93	40.3	143	61.9	193	83.6	243	105.3	293	126.9
44	19.0	94	40.7	144	62.4	194	84.0	244	105.7	294	127.3
45	19.5	95	41.1	145	62.8	195	84.5	245	106.1	295	127.8
46	19.9	96	41.6	146	63.2	196	84.9	246	106.6	296	128.2
47	20.3	97	42.0	147	63.7	197	85.3	247	107.0	297	128.6
48	20.8	98	42.4	148	64.1	198	85.8	248	107.4	298	129.1
49	21.2	99	42.9	149	64.5	199	86.2	249	107.9	299	129.5
50	21.6	100	43.3	150	65.0	200	86.6	250	108.3	300	129.9

HYDRAULIC WEIGHTS AND MEASURES.

1 U. S. Gallon	=231 Cubic Inches.
1 Cubic Foot	=7.48 U. S. Gallons.
1 Acre-Foot	=43,560 Cubic Feet.
1 Acre-Foot	=325,829 U. S. Gallons
1 Square Mile-Inch	=53.33 Acre-Feet.
1 Square Mile-Inch	=2,323,200 Cubic Feet.
1 Square Mile-Inch	=17,377,536 U. S. Gallons.
1 Cubic Foot per Second	=646,272 U. S. Gals. per day (24 hrs).
1 Cubic Foot per Second	=50 California Miner's Inches.
1 Cubic Foot per Second	=38.4 Colorado Miner's Inches
1 California Miner's Inch	=0.020 Cubic Feet per Second.
1 Colorado Miner's Inch	=0.026 Cubic Feet per Second.
1 Million U. S. Gallons per Day	=1.55 Cubic Feet per Second.
1 Foot of Depth	=0.433472 Pounds per Square Inch.
1 Pound per Square Inch	=2.307 Feet of Water.
1 Inch of Mercury at 32	=1.1334 Feet of Water.
1 Atmosphere (equals 29.922 Inches Mercury)	=33.9 Feet of Water.

1 Cubic Foot of Water per Second falling 1 ft vertical=0.1135 Horse Power (theoretical).
1 Cubic Foot of Water at 39.2° F. weighs 62.4 Pounds.
1 U. S. Gallon of Water at 39.2° F. weighs 8.34 Pounds.

Conservative Working Pressures for Good Grades of New Water Hose

Internal Diameter	Pressures, Pounds.									
	3-Ply	4-Ply	5-Ply	6-Ply	7-Ply	8-Ply	9-Ply	10-Ply	11-Ply	12-Ply
½ in.	236	315	393	472	551	630	708	787	866	945
¾ "	157	210	262	315	367	420	472	525	577	630
1 "	127	169	212	254	296	339	381	424	466	508
1¼ "	102	131	169	203	237	271	305	339	373	406
1½ "	91	122	152	183	213	244	274	305	335	366
1¾ "	78	104	130	156	183	209	235	261	287	313
2 "	72	96	120	144	168	192	216	240	264	288
2¼ "	64	85	107	128	149	171	192	214	235	256
2½ "	58	77	96	115	134	154	173	192	211	231
3 "	53	70	88	106	123	141	158	176	194	211
3½ "	45	60	75	90	106	121	136	151	166	181
4 "	43	57	72	86	100	115	129	143	158	172

CHAPTER VIII.

CONCRETE.

CEMENT.

The writer does not wish to be accused of plagiarism, and as many readers will recognize parts of this chapter, he wishes to make a preliminary explanation. Last year he wrote for a firm manufacturing a concrete mixer a little pamphlet entitled "Instructions to Agents." In preparing this chapter on concrete the scissors have been used pretty liberally on that pamphlet, and whole paragraphs have been used here without alteration. As many thousands of copies were distributed, it is more than likely some of the readers of this book will have read it. There is far more in this chapter, however, than the pamphlet contained.

Lime is an ordinary article of commerce, obtained by burning limestone to drive off the moisture and carbonic acid gas. By mixing lime with water into a paste the moisture is restored and the lime gradually absorbs from the atmosphere carbonic acid gas and will again become limestone.

If large quantities of lime-mortar are used in a mass of masonry it often happens that in the interior of the mass the mortar never hardens because the hardening of the mortar on the outside shuts off the supply of air on which it depends for a hardening element.

Sand is mixed with lime paste for three reasons:

1st. It is economical.

2d. It toughens the paste so that it does not crack in setting.

3d. It increases considerably the crushing strength. Lime and sand mortar, when set, is an artificial sandstone containing about 10

per cent carbonate of lime. The more sand, the quicker it will set, and the harder it will become up to a certain point where so much sand is used that the lime paste can not sufficiently bind the grains of sand together.

Cement is really a stone-forming material also, in which silica or sand forms one-quarter to one-third of the entire mixture, and lime is practically two-thirds of the mixture.

Alumina is the next principal ingredient and there are various other chemicals in small amounts, few of which are necessary, and some of which are impurities. Cement is so closely allied to lime that it is important to remember this connection.

Cement was developed because masons needed a mortar that would set beneath water and because they also wanted a mortar that would be durable when attacked by the elements.

Some men found, centuries ago, that common clay added to lime-mortar made it set much more rapidly and also made a very strong mortar. It was not a permanent mortar, however, because the clay would disappear when exposed to the elements. This was guarded against by having the mortar in the interior of the mass of masonry contain considerable clay, and on the outside the joints were grouted with a pure lime-mortar. This lime would harden, and as the years went by, become strong, so that the interior mortar was amply protected.

The ancients discovered that if clay was burned and ground to a very fine powder that it could be mixed with lime and a mixture was made which would set under water. This was the beginning of the manufacture of hydraulic mortar.

In the numerous volcanoes on the shores of the Mediterranean, the Romans found excellent kilns for preparing their hydraulic base for this lime-mortar. The dust most often used came from the village of Puzzuolo, hence the name generally given to Roman cements, Puzzuolani, or, as it is today spelled, "Puzzolan."

For this reason all the cements that are made by the addition of burned clay or volcanic dust, ashes or furnace slag, to lime, and then ground together without afterward burning them are called "Puzzolan" cements.

A few years ago some steel companies in the United States com-

menced the manufacture of a "Portland slag" cement, containing furnace slag, and such cements are now called "Puzzolan Cements." The change was made because the officers of the Corps of Engineers of the United States Army decided to designate cement which was not burned after the intimate mixing of the ingredients, a Puzzolan cement, for there are some true Portland cements made from furnace slag in which the materials are burned after being mixed together. The name "Portland Slag" was therefore dropped to prevent misunderstandings.

Natural cement is made from a limestone containing a considerable amount of clay. This stone is burned and ground as it comes from the earth, without any admixture of other materials. It is a good cement, but generally not suitable for sidewalk or building block work

In the specifications following, the differences between Portland and natural cements are made plain. While natural cement does not weather so well, it is excellent where kept continually moist. In any place where great strength is not required and where weight and mass count, natural cement is as good as Portland. When there is any material difference in price it pays to investigate the merits of natural cement.

Puzzolan cement is very strong, but must be mixed pretty dry, and is only useful in places where it can be kept continually moist, or where it can absorb considerable moisture. It is all right for street foundations, cellar floors, masonry walls along the banks of rivers, shores of lakes, etc. Where exposed to dry air it deteriorates by cracking and checking. This because the sulphides leach. It is dangerous to use in reinforced concrete.

Portland cement is so called because of its resemblance in color to the famous Portland building stone of England, and is an artificial product made by properly combining certain ingredients carrying lime, silica and alumina, and burning them at an intense heat; then grinding same, and to which no addition of chemical substances is made in excess of 3 per cent after burning.

An excess of lime in cement is harmful because it is likely to be free, and in that case will expand when setting and destroy the structure. As much cement as can be put on a five-cent nickel piece

can be moistened with about a half teaspoonful of water and a paste made. This paste can be covered with muriatic acid, gently poured on, and the mixture stirred with a glass stirring rod. If the cement is a pure Portland there will be a slight effervescence and a slight odor. At the conclusion of the operation a bright yellow jelly will be seen in the place of the paste. If there is considerable effervescence so that the acid seems to boil and a very distinct odor is given off it is plain that an excess of lime is in the cement. If the cement has been adulterated with silica there will be a heavy sediment in the jelly.

A word as to this adulteration with silica. When cement becomes high in price certain manufacturers place on the market a sand or silica cement. This is composed of Portland cement mixed with clean sand and then the two ground together. This grinding makes the cement very fine indeed and reduces the sand to a degree of fineness generally called for in the best cements. If properly done, it makes a very strong cement, but it is in reality an adulteration, and at the present low prices of cement there is no excuse for a man purchasing it. In the above test the sediment will indicate an adulteration of silica and the cement should be rejected.

To ascertain whether the cement is a Puzzolan requires a little more careful test, but in general, we can say that a Puzzolan cement is not gritty to the feeling like a true Portland cement, and instead of being a bluish gray color it is a light lilac in tint, approaching white. It is also much lighter than Portland, the specific gravity being much less.

If some cement is mixed into a paste on a glass or metal table, so that none of the moisture can escape, and made into pats, a pat of good cement will remain even in color. A pat of Puzzolan cement will show yellow, green and brown stains.

For years there have been many different requirements for cement, and in 1904 standard specifications were prepared. The readers of this book are asked to insert the following clause in all their specifications for cement.

"Cement furnished shall comply with the standard specifications prepared by the American Society for Testing Materials."

The methods proposed by the American Society of Civil Engineers are a part of the standard specifications.

REPORT OF COMMITTEE OF THE AMERICAN SOCIETY FOR TESTING MATERIALS.

ADOPTED BY THE SOCIETY, NOVEMBER 14, 1904.

ADOPTED BY THE ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS, JUNE 16, 1904.

ADOPTED BY THE AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION, MARCH 21, 1905.

GENERAL OBSERVATIONS.

1. These remarks have been prepared, with a view of pointing out the pertinent features of the various requirements and the precautions to be observed in the interpretation of the results of the tests.

2. The Committee would suggest that the acceptance or rejection under these specifications be based on tests made by an experienced person having the proper means for making the tests.

SPECIFIC GRAVITY.

Specific gravity is useful in detecting adulteration or underburning. The results of tests of specific gravity are not necessarily conclusive as an indication of the quality of a cement, but when in combination with the results of other tests may afford valuable indications.

FINENESS.

4. The sieves should be kept thoroughly dry.

TIME OF SETTING.

5. Great care should be exercised to maintain the test pieces under as uniform conditions as possible. A sudden change or wide range of temperature in the room in which the tests are made, a very dry or humid atmosphere, and other irregularities vitally affect the rate of setting.

TENSILE STRENGTH.

6. Each consumer must fix the minimum requirements for tensile strength to suit his own conditions. They shall, however, be within the limits stated.

CONSTANCY OF VOLUME.

7. The tests for constancy of volume are divided into two

classes, the first normal, the second accelerated. The latter should be regarded as a precautionary test only, and not infallible. So many conditions enter into the making and interpreting of it that it should be used with extreme care.

8. In making the pats the greatest care should be exercised to avoid initial strains due to molding or to too rapid drying out during the first twenty-four hours. The pats should be preserved under the most uniform conditions possible, and rapid changes of temperature should be avoided.

9. The failure to meet the requirements of the accelerated tests need not be sufficient cause for rejection. The cement may, however, be held for twenty-eight days and a retest made at the end of that period. Failure to meet the requirements at this time should be considered sufficient cause for rejection, although in the present state of our knowledge it can not be said that such failure necessarily indicates unsoundness, nor can the cement be considered entirely satisfactory simply because it passes the tests.

GENERAL CONDITIONS.

1. All cement shall be inspected.

2. Cement may be inspected either at the place of manufacture or on the work.

3. In order to allow ample time for inspecting and testing, the cement should be stored in a suitable weather-tight building, having the floor properly blocked or raised from the ground.

4. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment.

5. Every facility shall be provided by the contractor, and a period of at least twelve days allowed for the inspection and necessary tests.

6. Cement shall be delivered in suitable packages, with the brand and name of the manufacturer plainly marked thereon.

7. A bag of cement shall contain 94 pounds of cement net. Each barrel of Portland cement shall contatin 4 bags, and each barrel of natural cement shall contain 3 bags of the above net weight.

3. Cement failing to meet the seven-day requirements may be

held awaiting the results of the twenty-eight day tests before rejection.

9. All tests shall be made in accordance with the methods proposed by the Committee on Uniform Tests of Cement of the American Society of Civil Engineers, presented to the Society January 21, 1903, and amended January 20, 1904, with all subsequent amendments thereto.

10. The acceptance or rejection shall be based on the following requirements:

NATURAL CEMENT.

11. *Definition.* This term shall be applied to the finely pulverized product resulting from the calcination of an argillaceous limestone at a temperature only sufficient to drive off the carbonic acid gas.

SPECIFIC GRAVITY.

12. The specific gravity of the cement thoroughly dried at 100° C., shall be not less than 2.8.

FINENESS.

13. It shall leave by weight a residue of not more than 10 per cent on the No. 100, and 30 per cent on the No. 200 sieve.

TIME OF SETTING.

14. It shall develop initial set in not less than ten minutes, and hard set in not less than thirty minutes, nor more than three hours.

TENSILE STRENGTH.

15. The minimum requirements for tensile strength for briquettes one inch square in cross section shall be within the following limits, and shall show no retrogression in strength within the periods specified.*

Age.	*Neat Cement.*	*Strength.*
24 hours in moist air		50-100 lbs.
7 days (1 day in moist air, 6 days in water)		100-200 "
28 days (1 day in moist air, 27 days in water)		200-300 "

*For example the minimum requirement for the twenty-four hour neat cement test should be some specified value within the limits of 50 and 100 pounds, and so on for each period stated.

One Part Cement, Three Parts Standard Sand.

7 days (1 day in moist air, 6 days in water)..........	25- 75	"
28 days (1 day in moist air, 27 days in water).........	75-150	"

CONSTANCY OF VOLUME.

16. Pats of neat cement about three inches in diameter, one-half inch thick at center, tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

(a) A pat is then kept in air at normal temperature.

(b) Another is kept in water maintained as near 70° F. as practicable.

17. These pats are observed at intervals for at least 28 days, and, to satisfactorily pass the tests, should remain firm and hard and show no signs of distortion, checking, cracking or disintegrating.

PORTLAND CEMENT.

18. *Definition.* This term is applied to the finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition greater than 3 per cent has been made subsequent to calcination.

SPECIFIC GRAVITY.

19. The specific gravity of the cement, thoroughly dried at 100° C., shall be not less than 3.10.

FINENESS.

20. It shall leave by weight a residue of not more than 8 per cent on the No. 100, and not more than 25 per cent on the No. 200 sieve.

TIME OF SETTING.

21. It shall develop initial set in not less than thirty minutes, but must develop hard set in not less than one hour, nor more than ten hours.

TENSILE STRENGTH.

22. The minimum requirements for tensile strength for briquettes one inch square in section shall be within the following

limits, and shall show no retrogression in strength within the periods specified.*

Age.	*Neat Cement.*	*Strength.*
24 hours in moist air		150-200 lbs.
7 days (1 day in moist air, 6 days in water)		450-550 "
28 days (1 day in moist air, 27 days in water)		550-650 "
	One Part Cement, Three Parts Sand.	
7 days (1 day in moist air, 6 days in water)		150-200 "
28 days (1 day in moist air, 27 days in water)		200-300 "

CONSTANCY OF VOLUME.

23. Pats of neat cement about three inches in diameter, one-half inch thick at the centre, and tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

(a) A pat is then kept in air at normal temperature and observed at intervals for at least twenty-eight days.

(b) Another pat is kept in water maintained as near 70° F. as practicable, and observed at intervals for at least twenty-eight days.

(c) A third pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel for five hours.

24. These pats, to satisfactorily pass the requirements, shall remain firm and hard and show no signs of distortion, checking, cracking or disintegrating.

SULPHURIC ACID AND MAGNESIA.

25. The cement shall not contain more than 1.75 per cent of anhydrous sulphuric acid (SO_3) nor more than 4 per cent of magnesia (MgO).

CONCRETE.

Concrete is composed of sand, stone and cement; or gravel, sand and cement; or sometimes simply of cement with gravel as it is taken from the pit, having sufficient sand to practically fill the

*For example the minimum requirement for the twenty-four hour neat cement test should be some specified value within the limits of 150 and 200 pounds, and so on for each period stated.

voids; or it is composed of what is called "crusher run" stone. "Crusher run" stone is unscreened stone and the stone dust takes the place of sand in concrete.

Limestone is generally observed to be a good material when used in this way as from extensive experiments made it has been shown that only 11 per cent of voids are in the bulk.

The only objection to stone dust is that during the crushing some of it is ground nearly as fine as the cement and will collect in small lumps and masses throughout the concrete, thus preventing the thorough distribution of the cement. It is necessary, when using crusher run stone or bank gravel, to attend very carefully to the dry mixing of the aggregates before applying the water, and the water should be applied quickly and plentifully.

The writer believes that for very particular work it is best to screen the crusher run stone and afterward mix the various products of the screens to obtain the best results. He advises this also with gravel. An excess of mortar is weakening and as stone dust is seldom evenly distributed through the stone and the sand is seldom evenly distributed through the gravel there will be weak spots.

Cinders are used by fireproofing companies for making concrete. It is weaker than rock concrete, for the strength of concrete is governed by the strength of the aggregates. It is, however, lighter than rock concrete when strong enough for the purpose intended. Nails can also be driven in it and there are certain advantages possessed by this material that can not be overlooked.

The danger of cinder concrete is that there may be too many ashes in it and therefore the concrete will not be good. There may be a great deal of unconsumed coal in the cinders and this is a menace in case of fire. Certain coals have a high sulphur content. Cinder concrete made from cinders produced from such coal never stops expanding, apparently, and numbers of buildings have been damaged from this cause alone. Sulphur attacks metal badly, so that reinforced cinder concrete, made from cinders carrying much sulphur, will rapidly weaken.

In hand mixing there are two methods followed. Engineers often specify that the sand shall be spread out on a tight board platform and leveled off so that the depth will be three or four inches. Over this is spread the cement with a hoe, and after a pretense of dry mixing, enough of the material is drawn from the

middle of the pile to leave the sand and cement in a ring. Water is put into the center, and with hoes and shovels the sand and cement are turned over and over and the water incorporated with them until a thin paste is formed. The stone is wet and thrown into the paste and the mass is turned over and over until each particle of stone is thoroughly coated with the cement mortar. The object in wetting the stone is to prevent it absorbing enough water from the paste to injure it. This method is somewhat slow, and the way in which contractors hurry the mixing of sand and cement does not always produce a good mixture.

The specifications generally say that the mixing must continue until the color is uniform before the water is added, but a saving clause is generally added to the effect that "the mass must be turned over dry not less than twice."

Another way, generally followed by contractors when doing work for which no specifications have been prepared, and a method that is sometimes specified by engineers, is to spread the stone on a platform as many inches in depth as there are parts of stone in the mixture; then place on this sand as many inches deep as there are parts of sand in the mixture, and spread over the sand the cement.

To explain this, we will take, for instance, a mixture composed of one cement, three sand and five stone. Using one bag of cement as a unit, because it contains one cubic foot of cement, make a wooden box with a capacity of exactly five cubic feet. This box will have no bottom and no top; two of the sides will project enough so that handles can be formed by cutting the ends down to the proper size.

Place this box on the platform and fill it with the stone level to the top of the sides; by means of the handles lift the box to the side and then with hoes and shovels spread the stone out until it is about five inches in depth; on the top of this place a box of the same kind having a capacity of three cubic feet; fill it with sand, remove the box and spread the sand over the stone. As some of the sand is sure to go into the stone, it is customary to make the sand box about 5 per cent smaller in capacity than is indicated by the proportion of sand in the mixture. When the sand is spread over the stone empty a bag of cement on the sand and spread it out. Then let two men at one end shovel the mass over to the other end

of the platform. They are to put their shovels in at the bottom and turn them over so that the materials fall off the shovels and are not thrown off. The whole mass is moved about two feet to the side and then in the same manner shoveled back. This shoveling i: twice piles it up and distributes the cement and sand very thoroughly. Then have a man stand with a sprinkling pot to one side and the shovelers will shovel the mass over a third time while the water tender is sprinkling on the water. It is shoveled a fourth time to complete the diffusion of moisture and when it is put into the wheelbarrows it gets a fifth turning.

Some men dump the material directly from wheelbarrows into the structure and if the wall is a thick one, or if it is a large pier or a broad surface, like a sidewalk or floor, this is all right. Should the wall, however, be thin, or be a column or narrow structure, the best way is to take the material from the wheelbarrows in shovels and throw it into place. This should be done if the height is great; otherwise air will be trapped and the resulting concrete will not be uniform. Even tamping will not remove this lack of uniformity.

With walls, where the forms can be carried up a few feet at a time, throwing the concrete in with shovels, is the best way. Columns have the forms built the whole height. A method often adopted with this construction is to have a pipe made in sections with a flaring top. This pipe goes nearly to the bottom of the column and the concrete is poured into it. The pipe is raised from time to time and churned up and down. When it rises so that a section can be removed, this is done. Concrete for columns is generally softer than concrete for slabs and beams.

The old way of mixing concrete was to put in just as little water as will hold the cement-mortar together. This is what is called the "dry" method of mixing concrete. In this method, if a handful of concrete is taken up and squeezed it will retain its shape when the hand is opened; but will not be wet in appearance and will not stain the hand. Such concrete is generally deposited in place and tamped very thoroughly until the excess of moisture is driven to the top and the mass becomes quakey.

It is surprising to see how wet concrete will become under thorough tamping when to the eye it looks perfectly dry before being put in place.

This method was the only one permitted up to twelve or fifteen years ago by the majority of engineers.

It has been found by careful experiments made in hundreds of places that concrete mixed by this method is much stronger on short time tests than concrete mixed with an excess of moisture. When briquettes, however, are kept one or two years, and then tested, very little, if any, difference in strength can be observed. It therefore seems that when the excess of moisture disappears from the concrete the strengthening process goes on as it does when the concrete is mixed with just enough water to fulfill the theoretical requirements. If mixed too dry, the wetter mixed concrete soon surpasses it in strength.

Today we see the "dry" method used only in places where quick strength is required. That is, where a contractor is working on a time limit and must take his forms down quickly. It is also extensively used by building block men, for the reason that they must be able to take their blocks quickly from the moulds if they want to avoid a large investment in machinery. There are some block machines in the market that could not exist if the concrete were not mixed "dry." There are other machines so constructed that concrete can be mixed fairly wet, and others so made that the concrete is mixed as wet as soup, and poured in. Each manufacturer claims that his method is absolutely "the best."

In a wet mix the concrete may be simply a little wetter than a "dry" mix, or it may be so wet that it will run. All contractors who advocate wet mixtures have their preferences for some particular degree of moisture.

The advantage claimed for the wet mixture is that the material will require less tamping and will flow into place, producing a better surface on the face of wall and all exposed surfaces. It is also believed by a great many contractors that there is considerable labor saved when mixing concrete wet, for they say the water distributes the cement throughout the mass better than shovels can do it. Other men dispute this and state that an excess of water simply gives the concrete a well mixed appearance, without, in fact, improving the mixture. They claim that it is only possible to get a thorough mix by hand by using the "dry" method.

In an extremely wet mixture there is a slight tendency during the setting process for the cement, because of its heavier specific

gravity, to settle to the bottom, and this produces a concrete that is not uniform. This is an honest objection to extremely wet concrete.

It has an advantage, however, in this: Re-inforced concrete is coming greatly into use. As the metal is placed in the lower part of the structure, if there is any tendency of the cement to go to the bottom it is apt to get into the part of the beam where the steel is placed and will there cover the steel in such a manner as to thoroughly protect it. In fact, the great use of steel re-enforcement in concrete is largely responsible for the increased favor with which wet mixtures are regarded by workers in concrete. Re-inforcing steel should always be painted with neat cement mortar.

Concrete surfaces should never be plastered. When specifications are prepared that call for plastering the face of concrete it may be set down that the man writing the specifications knew little about his business, and is not fit to write specifications for concrete work.

An exception, however, is made when the plaster coat can be applied to the concrete before it is set. This happens with sidewalks, floors and curbing. With concrete deposited in forms, however, no plastering can be placed on the face of the concrete after the forms are removed. It will not adhere properly.

Forms should be treated with crude oil or a mixture of soap, when a smooth surface is wanted. The men should be supplied with flat, narrow spades or with tools like potato forks, with which to spade and work the material next the face, so the mortar can flow there and not permit stones to show. This is practically the only way to get a good face.

Concrete should be kept moist for at least ten days after it is deposited in place. Cement requires moisture to set it, and if that moisture is not supplied with the mixture, then it must be supplied afterwards, so it is customary to cover all completed structures with wet earth, sand, cloth, or other materials that will retain moisture, in such a way that the concrete can absorb the moisture.

When moisture is supplied with the mixture then the cement, in the process of setting, will absorb the excess. This is the reason that in long time tests, concrete mixed very wet shows up as well

as concrete mixed dry and kept moist during the process of setting.

In testing cements in a laboratory the briquettes are kept in the air at a temperature of about 70 degrees until they have attained their initial set, which requires from half an hour to three hours. They are then placed in a box with shelves, having water in the bottom of it, and the sides hung with damp cloths. In this box they are kept twenty-four hours. Some of them are then kept in the air until tested, and others are kept in water. Those kept in water generally show the greatest strength and defects show up more quickly in those kept in the air than in those kept in water. This shows that water is essential in the setting of concrete, but in the mixing of concrete the amount of water depends entirely upon the judgment of the man using same, provided he does not mix the mortar as thin as milk, so that the cement will be washed out. Every drop of water added to a concrete mixture after it has just enough retards its setting.

CONCRETE MIXTURES.

A man starting in the concrete business hears a great deal about the relative strength of mixtures. Some men tell him to use a 1-2-3; others say a 1-2-4 is better; some scoff at these and say that a 1-3-6 is strong enough, while still others will tell about leaner mixtures and the wonderful strength obtained.

Concrete has a compressive strength varying from say 600 pounds to the square inch—such as we see in a great many dry mixed building blocks—to a strength as great as 4,000 pounds to the square inch. The latter strength was obtained with concrete bars made for testing purposes and cured under water. Concrete should have a compressive strength of fully 2,000 pounds to the square inch. The strength of concrete depends entirely upon how well the voids are filled with the cementing medium. Therefore, a lean mixture, thoroughly mixed, will oftentimes attain as great strength as a fatter mixture.

The terms "fat" and "lean" are used among European engineers and scientific men generally to indicate the amount of cement in the concrete. A "fat" mixture varies from one part of cement to one part of sand, to a mixture of one part of cement, two parts of sand and four parts of small broken stone or clean

gravel. Any concrete having a smaller proportion of cement is called a "lean" mixture.

In the United States a great many men speak of the fat mixture as being "rich" and the lean mixture as being a "poor" mixture, meaning that one is rich in cement and the other is poor in cement. These terms, however, are not correct when it is considered that a lean mixture, although containing a less amount of cement than a fat mixture, is not a poor mixture. Whether one is as strong as the other in compressive strength depends largely upon the degree of care exercised in distributing the cement-mortar throughout the mass.

The voids in broken stone, sand and gravel or other materials used in making concrete vary from 33 per cent to 50 per cent of the entire mass. In order to get a good mixture it is generally figured that the stone contains 50 per cent of voids and that the sand contains 50 per cent of voids—the cement to fill the voids in the sand and be slightly in excess.

On this basis the theoretically perfect mixture, in which stone is used, is 1-2-4, for the reason that the sand and stone are generally mixed loose and the voids will, therefore, be about 50 per cent. If shaken in the measuring box, or slightly tamped, the proportion of voids can be reduced to about one-third of the mass.

A neat mortar is composed of cement alone and is supposed to be water tight, although that depends upon the amount of water used in mixing and the care taken in curing. If not cured properly it will crack. A mixture of one part of cement up to three parts of sand will be water tight if properly mixed and thoroughly tamped. A mixture of 1-3-5 may be water tight also if properly mixed and thoroughly tamped, but that again depends upon the porosity of the stone used. As a rule a leaner mixture than one part of cement to three parts of sand can not be expected to be water tight when any stone is used.

There are a number of proportions used generally by engineers and contractors. Some men have a preference for one proportion and some for another, and it is not worth while to argue as to the respective merits of the different mixtures, for the reason that perfect concrete is that in which the voids in the stone are filled with sand and the voids in the sand are filled with cement, all so thoroughly mixed together that every particle of sand is coated

with cement and every particle of stone is entirely coated with the sand and cement-mortar. Any mixture of concrete may be strong, provided the materials are uniformly distributed throughout the mass, and it is so well tamped that all the stone and sand can be cemented together by the cement. A 1-2-4 mixture may be a perfect mixture for some sizes of sand and stone and yet not be a perfect mixture when the stone is broken into larger sizes. The size of the stone is not of great consequence otherwise.

The table presented herewith shows how the proportions vary with different sizes of aggregates.

Mixtures			Stone, 1 inch and under, dust screened out			Stone, 2½ inch and under, dust screened out			Stone 2½ inch, with most small stone screened out			Gravel, ¾ inch and under		
Cement	Sand	Stone	Cement, bbls.	Sand, cu. yds.	Stone, cu. yds.	Cement, bbls.	Sand, cu. yds.	Stone, cu. yds.	Cement, bbls.	Sand, cu. yds.	Stone, cu. yds.	Cement, bbls.	Sand, cu. yds.	Stone, cu. yds.
1	2.0	4.0	1.46	0.44	0.89	1.48	0.45	0.90	1.53	0.47	0.93	1.34	0.41	0.81
1	2.5	5.0	1.19	0.46	0.91	1.21	0.46	0.92	1.26	0.48	0.96	1.10	0.42	0.83
1	3.0	5.0	1.11	0.51	0.85	1.14	0.52	0.87	1.17	0.54	0.89	1.03	0.47	0.78
1	3.0	6.0	1.01	0.46	0.92	1.02	0.47	0.93	1.06	0.48	0.97	0.92	0.42	0.84
1	3.0	7.0	0.91	0.42	0.97	0.92	0.42	0.98	0.94	0.42	1.05	0.84	0.38	0.89
1	4.0	7.0	0.83	0.51	0.89	0.84	0.51	0.90	0.87	0.53	0.93	0.77	0.47	0.81
1	4.0	8.0	0.77	0.47	0.93	0.78	0.48	0.95	0.81	0.49	0.98	0.71	0.43	0.86

(From paper on "Concrete" by Chas. Matchem.)

When the best concrete obtainable is wanted the proportions should be fixed by the cement mortar. The following extract from specifications recently prepared by the writer for a reinforced concrete chimney illustrates this:

> "The concrete shall be mixed as follows: One bag of cement shall be considered to be one cubic foot and the cement mortar shall be mixed in the proportion of one part of cement by measurement with two parts of clean sharp sand by measurement. If mixed by hand the sand and cement shall be mixed dry until an absolutely uniform color is obtained and then water shall be added to make a paste the consistency of thick cream."
>
> "The voids in the stone having been first ascertained, enough cement mortar shall be used to completely fill the voids. If the voids exceed one-third the mass they are to be reduced by

> means of screened gravel or small stone to the required amount. Sand shall not be used to reduce the voids in the stone. The percentage of cement mortar in the concrete shall not exceed thirty-three (33) per cent, nor be less than twenty-five (25) per cent."

The foregoing is for a certain piece of work. It can be varied. It is better always to prescribe the cement mortar and determine the voids in the stone.

A great many men want rules for estimating quantities of aggregates when the voids are not known, but must be assumed. There are several rules in common use, but it must be remembered they are only true for certain proportions of voids and are simply good for purposes of estimating.

Assume an example where the mixture is 1 to 8 gravel and cement. Assume that bank gravel contains 20 per cent of voids. There are 27 cubic feet in one yard. Add to this 20 per cent and the total equals 32.4 cubic feet. By one rule one-ninth of this is cement. By another rule one-eighth is cement. Count 3.8 cubic feet per barrel and this gives practically one barrel of cement per yard of concrete.

Some men count the cement as one-ninth of the mass provided all the voids are filled. Others claim that the 20 per cent of voids in the gravel can be filled with fine sand and this sand will contain voids that cement will fill. Therefore they count the cement as being simply one-eighth of the mass.

Assume a mixture of 1 cement, 3 sand and 5 broken stone. The stone contains 40 per cent of voids. The sand contains 35 per cent of voids. As the voids in the sand are less than the voids in the stone and the proportion of cement is fixed, we will neglect them.

Multiply 27 cubic feet by the percentage of voids in the stone and add this to 27. Divide by the sum of the parts of sand (3) and stone (5), a total of eight. Multiply by 3 and divide by 27 to get the cubic yards of sand. Multiply by 5 and divide by 27 to get the cubic yards of stone. To get the number of barrels of cement divide the cubic feet of sand by 3, as there happens to be three times as much sand as cement. This result divided by 3.8, the cubic feet of cement per barrel, gives the number of barrels of cement.

The above rule fixes the cement as a proportion of the sand, as fixed in the specifications. Some men would have divided the large amount first obtained by the sum of the cement, sand and stone, making 9 instead of 8, and proportioned the aggregates in that manner.

A general rule used by a number of men is credited to Mr. Fuller. It is simply to add the number of parts, thus: 1 plus 3 plus 5 equals 9, and divide by 11, to get the number of barrels of cement. If the barrel is assumed to hold 3.8 cubic feet, multiply by 3.8 to get cubic feet, and multiply by 3 to get cubic feet of sand, and by 5 to get cubic feet of stone. If the cement barrel contains less than 3.8 cubic feet of cement the rule is worthless. It is assumed also for a certain percentage of voids in sand and stone. The rule first above given can be used with any percentage of voids or with any size cement barrel.

Hand mixing is being supplanted by machine mixing and there are a number of machines in the market. The writer classifies them as follows:

1st. A stationary receptacle without inside deflectors.
2nd. A stationary receptacle having fixed deflectors.
3rd. A stationary receptacle with movable deflectors.
4th. A movable receptacle with stationary deflectors.
5th. A movable receptacle with movable deflectors.
6th. A movable receptacle without inside deflectors.

The machine mixing of concrete is required in all good work today, so a man doing extensive work and not using a mixer is behind the times.

The proper kind of machines does the work cheaper than by hand and the mix is more thorough.

CONCRETE BLOCK SPECIFICATIONS

The following specifications for the manufacture of hollow concrete building blocks are proposed as a standard by a Committee on Standard Specifications of the National Association of Building Block Machinery Manufacturers.

DEFINITIONS.

SAND—Such material as will pass through a screen with ¼-inch mesh and is retained on screen with a No. 40 mesh. This

applies to river sand, bank sand or screenings from a stone crusher.

GRAVEL—Material obtained either from a bank or a river of such size as is retained on a screen having a ¼-inch mesh.

CRUSHED STONE—Such stone from a crusher as is retained on a ¼-inch screen.

BANK GRAVEL—Such material as is obtained from a pit or river containing both sand and gravel.

AGGREGATE—Any material such as broken stone, gravel or such fragments used with cement and sand mortar in making concrete for the purpose of reducing the cost and adding to the strength.

VOIDS—The space existing between particles of sand, crushed stone or materials of which an aggregate is composed.

CEMENT—Any Portland cement which will pass the tests required by the American Society for Testing Materials.

QUALITY OF SAND.

Sand suitable for concrete work must not be finer than the above described; must be sharp and gritty; not soft or loamy; must be free from loam or other foreign material, and must not contain any perceptible amount of clay, or other soluble matter. Some authorities concede that clay to the extent of 10 per cent in sand or gravel is not harmful. This committee is of the opinion that any perceptible amount of clay is unsafe. Crushed stone must be reasonably free from dust and must be retained on the same size screen as the bank sand, viz., ¼-inch. Gravel or crushed stone must be free from loam, dust or other foreign material, and must contain no soft or rotten stone.

DETERMINATION OF AMOUNT OF CEMENT TO BE USED WITH AGGREGATES.

A theoretically correct concrete should consist of sand and gravel or crushed stone or a combination of them, containing any amount of cement equal to the voids in such combination. In other words, interstices should be filled with cement. To state this in another way, if the concrete is made up of sand and gravel, such proportion of cement should be used with the sand as is equal to the voids in the sand, and such quantity of this resulting mortar of sand and cement should be used with the crushed stone or gravel as will fill all the voids in the crushed stone or gravel.

Restating this in a few words, the cement should fill the voids in the sand and the resulting mortar should fill the voids in the aggregate.

DETERMINATION OF VOIDS.

To determine the voids in the sand, or the material to be used as an aggregate, what is known as the "water test" is employed. In preparing for this test the sand or gravel must be perfectly dry. Sand has a greater volume when wet.

A receptacle holding a known amount, such as a quart jar, is filled with the material to be tested, sand, for example, and into this receptacle is poured as much water as the sand or other material will absorb. The water should be measured. The amount of water absorbed indicates the voids, and also indicates the exact amount of cement which it is necessary to use in order to produce a solid concrete.

In making hollow blocks if no gravel or other coarse aggregate is used, the result of this test should give the proportions of sand and cement to be used in block manufacture. Average sand will absorb 25 to 35 per cent of water, indicating from 25 to 35 per cent of voids, also indicating that the proportion to one part of cement to from three to five parts of sand are required to make a solid concrete.

The proper selection of sand and aggregate material is important. Care should be taken that the particles vary so in size as to reduce the voids to the smallest amount possible. With this careful selection the amount of cement required to produce good work is greatly reduced.

MIXING.

After the materials are selected they should be mixed together dry until thoroughly incorporated, or in other words, until the mass is of an absolutely uniform color. Water should then be applied and the thorough mixing repeated. The amount of water should be in all cases as great as possible without causing the materials to stick to the molds when the stone is removed. A little more care in the treatment of the face plates of any machine will enable the manufacturer to use a wetter concrete than is usually employed. Only such size batches should be mixed at one time as can be used up within thirty minutes from the time the water has been added.

MANUFACTURING.

The concrete should be placed in the mold in small quantities and tamping should begin immediately upon the placing of the first shovelful, and continue until the mold is full. The material should be tamped with a tamper having a small face, and short, quick, sharp blows should be struck.

In faced blocks the face should be composed of two parts sand and one part of cement, the same being mixed in the manner described above.

Owing, however, to the excess of cement used in facing, and owing, further, to the fact that the cement is what makes the concrete sticky, the facing can not be used as wet as the balance of the block is made. Great care should be taken to tamp the concrete thoroughly into the facing so as to unite the two into one solid stone.

In the wet process the amount of water used is such as will produce a plastic, or flowing, condition in the concrete, but not enough to wash the cement from the other material. When placing the material in the molds the entire mold is filled with one pouring.

No stone having transverse ties or webs cracked should be used, or even allowed to cure. Should a slight crack occur in moving the green stone, throw the material back, and make it over. In no case use a cracked stone in a building.

CURING.

All stone made by the medium wet or medium dry process should be made under cover, and kept under cover for at least ten days, protected from the dry currents of air. If shed room is not available to store a ten days' output, the blocks should be carried out after the initial set has taken place, and covered with canvas, hay or other covering, which will retain moisture, and at the same time keep the dry air from circulating around the block. Under no circumstances should blocks be made under the direct rays of the sun, nor should blocks made by this process be exposed to either sunshine or dry winds while curing.

The blocks should be gently sprinkled as soon as possible after making, that is, just as soon as the cement has set sufficiently so that it will not wash. Blocks should be kept wet from ten days to

two weeks, and should never be removed from the yard for the purpose of using in a building until they are from thirty to sixty days old. This is very important. A green block will surely crack in the building on account of shrinkage.

LAYING.

In laying cement stone a soft mortar composed of one-half cement mortar and one-half lime mortar should be used. This mortar should be made with fine sand free from stone and should be buttered on the ends of the stone before laying. The stone should be laid in the mortar and work down. Do not leave end joints open until after the building is completed, because when the end joints are filled at this time shrinkage in mortar is liable to loosen it, causing the mortar to fall out, leaving openings through the wall. The spreading of mortar is very important, because if mortar is unevenly spread so that it is thicker under one portion of the stone than under the other, a leverage is created, which under the weight of the wall above is liable to produce a crack in the stone.

COLORING.

In using coloring matter with concrete, the color should always be mixed with the cement dry, before any sand or water are added. This mixing should be thorough, so that the mixture is uniform in color. After this mixing the combination is treated in the same way as clear cement.

The writer wishes to add to the above that the mortar recommended is, in his opinion, too rich in lime and the excess of lime will create an efflorescence in the face of the block. Very few concrete block buildings look good in the joints.

There is today on the market a material known as Bricklayers' Cement, manufactured in Louisville, Ky., that is excellent for cement block joints. It is made by grinding 15 per cent of hydrated lime with calcined cement stone to a powder that leaves only 5 to 8 per cent on a sieve of 10,000 meshes per inch, thus securing a perfect mixture in proper proportions, much better than any dry mixing attempted by hand.

All blocks should be thoroughly wet on the sides to which the mortar is applied. Not simply wet with a brush passed hastily over, but soaked like brick are soaked. Unless this is done the blocks will absorb the moisture from the mortar like dry bricks and there will be no perfect bond.

The writer has found nothing equal to retempered mortar for cementing concrete building blocks. It is very slow setting and the adhesiveness being somewhat destroyed by the retempering an addition of from ten to fifteen per cent of hydrate of lime restores it. Retempered mortar works nearly as well under the trowel as lime and cement mortar mixed half and half. Being so slow setting, it takes readily the weight of the stone wall and variations in thickness make little difference. It is not so much a difference in thickness as it is a difference in density of the mortar. A thoroughly worked retempered mortar is creamy and when spread is of fairly uniform density and if care is taken to make the thickness uniform the slow setting while the wall is settling prevents the leverage spoken of in the proposed standard specifications.

COLORING.

The specifications for mixing coloring matter are excellent, but they do not go far enough.

Coloring matter containing acids will attack the akaline substances in cement and destroy it. Be careful, therefore, in selecting the coloring pigment and do not be too free in coloring concrete work. All the materials used weaken cement except ultramarine. This seems to add somewhat to the strength.

To make a gray surface more pleasing to the eye than the natural cement color, use not to exceed one pound of lampblack to a bag of cement or four pounds per barrel.

The writer has attended cement conventions and listened to papers on coloring cement work and has mingled with men who have related to him many different kinds of experiences with coloring matters. His only personal experience has been with lampblack and with Pikron. It is unwise to use more lampblack than mentioned above and he does not think it well to use more than half that amount. Pikron was used by him on the Pacific Coast fifteen years ago to get a better gray than lampblack yielded safely.

It was mixed with the water and made it look like ink. He has seen no advertisements of this material in several years.

What follows on the coloring of cement is not from the writer's experience, but is culled from many sources.

For green use 5 lbs. of ultramarine, and for blue use 6 to 7 lbs. of ultramarine per bag of cement, or four times those amounts respectively per barrel.

One authority says 2 lbs. of Excelsior Carbon Black per bag or 8 lbs. per barrel will make a good black. Another says use from 10 to 11 lbs. of manganese dioxide per bag or from 40 to 45 lbs. per barrel.

Use 6 lbs. per bag or 24 lbs. per barrel of Roasted Iron Oxide for brown. Yellow Ochre makes yellow when 6 lbs. per bag or 24 lbs. per barrel are used and it makes buff when the quantities are nearly doubled.

An ordinary red can be made with from 6 to 10 lbs. per bag, or from 24 to 40 lbs. per barrel of Red Iron Oxide. A bright red can be obtained with 6 lbs. per bag, or 24 lbs. per barrel of Pompeiian Red.

So-called white cement is often merely plaster of Paris. At Sandusky a white cement is made that is claimed to be a true Portland. The cement, however, constitutes such a small portion of the concrete that care must be taken to use white aggregates when trying to approximate to a pure white.

A pure white can not be obtained. The writer has seen some marvelously good work, however, when white cement was used with marble chips instead of stone and marble dust instead of sand. He has seen good results obtained with light colored stone, perfectly clean water, marble dust and screenings instead of sand and a final dusting of marble dust before the concrete was dry.

RETEMPERED MORTAR.

It is common to see a clause in specifications forbidding the use of mortar that has commenced to set. Today, however, it is well known that retempered mortar has a value. If allowed to set for about half an hour and then worked very vigorously for ten or fifteen minutes the time of ultimate set is prolonged.

There is no decrease in strength until after the second or third re-working. There is sometimes a slight loss in adhesiveness. This

is restored by adding 10 or 15 per cent of hydrate of lime to the mortar.

It is a difficult matter to make fresh concrete join to old work. The ordinary way is to clean the old surface and thoroughly wet it. Then put the new concrete against it. The writer prefers to wash the cleaned surface with a one per cent solution of sulphuric acid and then put on a layer of retempered mortar, after washing off with clean water the acid wash. The retempered mortar is slow setting and interposes betwen the old, hard set concrete and the new, quick setting concrete, a layer of material that will join to both. It forms, as it were, an elastic joint during the time the new concrete is setting.

In repairing the surface of sidewalks retempered mortar is good. First cut the broken place down half an inch or more with square edges. Then clean the space with a wire brush and wash it with a one or two per cent solution of sulphuric acid. Mix a batch of rich mortar, about one to one, cement and sand, and allow it to stand thirty minutes. Then with a hoe and shovel work it vigorously and thoroughly until it is like a smooth working dough. Wash off the acid with clean water and put the retempered mortar in the space. It must be more vigorously trowelled than is usual for such work. After a little experience a mason can make such repairs in a way that will defy detection.

PROPORTIONING AGGREGATES TO FILL VOIDS.

In the proposed standard specifications for building blocks it is stated that voids in materials can be determined by using a small amount and pouring in water. In the opinion of the writer the amount is too small.

His method is as follows: Use a box containing about five cubic feet and fill it flush with the stone, or largest sized aggregate. Pour in water gently in order that no air will be trapped and measure the water as it goes in. The amount of water used determines the amount of finer material necessary to exactly fill the voids.

Empty the box on a platform and spread the material in a thin layer, allowing the water to run off. Then cover it with the next smaller size of aggregates as determined by the amount of water used to fill the voids and turn the whole mass over with shovels

until well mixed. Then shovel it into the box, tamping it so the whole amount will go in. Should it more than fill the box screen the remainder to separate the sizes and remove from the box enough of the smaller size material to permit the surplus of the screened large material to go in. In this way all the coarser material will be in the box and enough of the smaller material to pack the voids.

Fill the box again with water. This amount of water represents the amount of the next smaller sized material necessary. Take for example that stone, gravel and sand are being used. The first aggregate tested for void was the stone. The second test was the stone and gravel. The third test is for stone, gravel and sand.

The material necessary to fill the voids, after screening surplus, must be placed on a memorandum. The amount was found by using water, but when placing in the box it will be found that on account of the sizes of the smaller sized aggregate some will not pack in like sand or cement.

Having filled the box again with water empty on the platform and spread the aggregates. Cover them with the amount of sand indicated by the water test and turn over thoroughly until mixed. Then place in the box in small amounts and tamp into place.

Having filled the box, after screening surplus as above directed, and ascertained the amount of stone, sand and gravel, pour in a measured quantity of water again until the box is filled. This last amount of water represents the amount of cement paste necessary to finally fill all the voids.

By proceeding in the above manner with graded sizes of materials the voids can be reduced as low as 7 per cent. This means a saving in cement. A lean concrete thus made will be remarkably strong in compression.

In drawing up specifications the amounts of each size of aggregates used can then be specified and the mixing will do the rest.

STANDARD SPECIFICATIONS FOR CEMENT HOLLOW BUILDING BLOCKS

ADOPTED JANUARY, 1908, BY THE NATIONAL ASSOCIATION OF CEMENT USERS. PHILADELPHIA, PA.

REGULATIONS GOVERNING USE AND MANUFACTURE.

Hollow cement blocks made in accordance with the following specifications, and meeting the requirements thereof, may be used in building construction,

subject to the usual form of approval, required of other materials of construction, by the bureau of building inspection.

CEMENT.—The cement used in making blocks shall be Portland cement, capable of passing the requirements as set forth in the "Standard Specifications for Cement," of the American Society for Testing Materials, and adopted by this Association (Specification No. 1) January, 1906.

SAND.—The sand used shall be suitable siliceous material, passing the one-forth in mesh sieve, clean, gritty and free from impurities.

STONE AGGREGATE.—This material shall be clean broken stone, free from dust, or clean screened gravel passing the three-quarter (¾) inch and refused by the one-quarter (¼) inch mesh sieve.

UNIT OF MEASUREMENT.—The barrel of Portland cement shall weigh 380 pounds net, either in barrels or sub-divisions thereof, made up of cloth or paper bags, and a cubic foot of cement shall be called not to exceed 100 pounds or the equivalent of 3.8 cubic feet per barrel. Cement shall be gauged or measured either in the original package as received from the manufacturer, or may be weighed and so proportioned; but under no circumstances shall it be measured loose in bulk.

PROPORTIONS.—For exposed exterior or bearing walls.

(*a*) Hollow cement blocks, machine made, using semi-wet concrete or mortar, shall contain one (1) part cement, not to exceed three (3) parts sand, and not to exceed four (4) parts stone of the character and size before stipulated. When the stone shall be omitted the proportions of sand shall not be increased, unless it can be demonstrated that the percentage of voids and tests of absorption and strength allow in each case of greater proportions with equally good results.

(*b*) When said blocks are made of slush concrete, in individual molds and allowed to harden undisturbed in samc before removal, the proportions may be one (1) part cement to not exceed three (3) parts sand and five (5) parts stone; but in this case, also, if the stone be omitted the proportion of sand shall be not increased.

MIXING.—Thorough and vigorous mixing is of the utmost importance.

(*a*) Hand mixing. The cement and sand in correct proportions shall first be perfectly mixed dry, the water shall then be added carefully and slowly in proper proportions and thoroughly worked into and throughout the resultant mortar; the moistened gravel or broken stone shall then be added either by spreading the same uniformly over the mortar, or spreading the mortar uniformly over the stones, and then the whole mass shall be vigorously mixed together until the coarse aggregate is thoroughly incorporated with and distributed without the mortar.

(*b*) Machine mixing. Preference shall be given to machine mixers of suitable design and adapted to the particular work required of them; the sand and cement, or sand and cement and moistened stone shall, however, be first thoroughly mixed before the addition of water, and then continued until the water is uniformly distributed or incorporated with the mortar or concrete; *provided*, however,

that when making slush or wet concrete (such as will quake or flow) this procedure may be varied with the consent of the bureau of building inspection, architect or engineer in charge.

MOLDING.—Due care shall be used to secure density and uniformity in the blocks by tamping or other suitable means of compression. Tamped blocks shall not be finished by simply striking off with a straight edge, but, after striking off, the top surfaces shall be troweled or otherwise finished to secure density and a sharp and true arris.

CURING.—Every precaution shall be taken to prevent the drying out of the blocks during their initial set and first hardening. A sufficiency of water shall first be used in the mixing to protect the crystallization of the cement, and, after molding, the blocks shall be carefully protected from wind currents, sunlight, dry heat or freezing for at least five (5) days. during which time additional moisture shall be supplied by approved methods, and occasionally thereafter until ready for use.

AGEING.—Hollow cement blocks in which the ratio of cement to sand be one-third (⅓) (one part cement to three parts sand) shall not be used in the construction of any building until they have attained the age of not less than three (3) weeks.

Hollow cement blocks in which the ratio of cement to sand be one-half (½) (one part cement to two parts sand) may be used in construction at the age of two (2) weeks, with the special consent of the bureau of building inspection and the architect or engineer in charge.

Special blocks of rich composition, required for closures, may be used at the age of seven (7) days with the special consent of same authorities.

The time herein named is conditional, however, upon maintaining proper conditions of exposure during the curing period.

MARKING.—All cement blocks shall be marked, for purposes of identification, showing name of manufacturer or brand, date (day, month and year) made, and composition or proportions used: as, for example, 1-3-5, meaning one cement, three sand and five stone.

THICKNESS OF WALLS.—The thickness of bearing walls for any building where hollow cement blocks are used may be ten (10) per cent less than is required by law for brick walls. For curtain walls or partition walls, the requirements shall be the same as in the use of hollow tile, terra cotta or plaster blocks.

PARTY WALLS.—Hollow cement blocks shall not be permitted in the construction of party walls, except when filled solid.

WALLS—LAYING OF.—Where the face only is of hollow cement block, and the backing is of brick, the facing of hollow block must be strongly bonded to the brick, either with headers projecting four (4) inches into the brick work, every fourth course being a header course, or with approved ties, no brick backing to be less than eight (8) inches. Where the walls are made entirely of concrete blocks, but where said blocks have not the same width as the wall, every fifth course shall extend through the wall, forming a secure bond, when

not otherwise sufficiently bonded. All walls, where blocks are used, shall be laid up with Portland cement mortar.

GIRDERS OR JOISTS.—Wherever girders or joists rest upon walls so that there is a concentrated load on the block of over two (2) tons, the blocks supporting the girder or joists must be made solid for at least eight (8) inches from the inside face. Where such concentrated load shall exceed five (5) tons, the blocks for at least three courses below, and for a distance extending at least eighteen (18) inches each side of said girder, shall be made solid for at least eight (8) inches from the inside face. Wherever walls are decreased in thickness, the top course of the thicker wall shall afford a full solid bearing for the webs or walls of the course of blocks above.

LIMIT OF LOADING.—No wall, nor any part thereof, composed of hollow cement blocks shall be loaded to an excess of eight (8) tons per superficial foot of the area of such blocks, including the weight of the wall, and no blocks shall be used in bearing walls that have an average crushing at less than 1,000 pounds per square inch of area at the age of twenty-eight (28) days; no deduction to be made in figuring the area for hollow spaces.

SILLS AND LINTELS.—Concrete sills and lintels shall be reinforced by iron or steel rods in a manner satisfactory to the bureau of building inspection and the architect or engineer in charge, and any lintels spanning over 4 feet 6 inches shall rest on block solid for at least 8 inches from the face next to the opening and for at least three courses below the bottom of the lintel.

HOLLOW SPACE.—The hollow space in building blocks used in bearing walls shall not exceed the percentage given in the following table for different height walls, and in no case shall the walls or webs of the block be less in thickness than one-fourth their height. The figures given in the table represent the percentage of such hollow space for different height walls:

Stories	1st	2d	3d	4th	5th	6th
1 and 2	33	33				
3 and 4	25	33	33	33		
5 and 6	20	25	25	33	33	33

APPLICATION FOR USE.—Before any such material be used in buildings, an application for its use and for a test of the same must be filed with the bureau of building inspection. In the absence of such a bureau, the application shall be filed with the chief of any department having such matters in charge. A description of the material and a brief outline of its manufacture and proportions used must be embodied in the application. The name of the firm or corporation, and the responsible officers thereof, shall also be given, and changes in same thereafter promptly reported.

PRELIMINARY TEST.—No hollow cement blocks shall be used in the construction of any building unless the maker of said blocks has submitted his product to the full tests required herein, and placed on file with the bureau of building inspection, or other duly authorized official, a certificate, from a reliable testing laboratory, showing that representative samples have been tested and

successfully passed all the requirements hereof, and giving in detail the results of the tests made.

No cement blocks shall be used in the construction of any building until they have been inspected and approved, or, if required, until representative samples be tested and found satisfactory. The results of all tests made, whether satisfactory or not, shall be placed on file in the bureau of building inspection. These records shall be open to inspection upon application, but need not necessarily be published.

ADDITIONAL TESTS.—The manufacturer and user of such hollow cement blocks, or either of them, shall, at any and all times, have made such tests of the cements used in making such blocks, or such further tests of the completed blocks, or of each of these, at their own expense and under the supervision of the bureau of building inspection, as the chief of said bureau shall require.

In case the results of tests made under this condition should show that the standard of these regulations is not maintained, the certificate of approval issued to the manufacturer of said blocks will at once be suspended or revoked.

CERTIFICATE OF APPROVAL.—Following the application called for in Clause No. 18, and upon the satisfactory conclusion of tests called for, a certificate of approval shall be issued to the maker of the blocks by the bureau of building inspection. This certificate of approval will not remain in force for more than four months, unless there be filed with the bureau of building inspection, at least once every four months following, a certificate from some reliable physical testing laboratory showing that the average of at least three (3) specimens tested for compression and at least three (3) specimens tested for transverse strength comply with the requirements herein set forth, the said samples to be selected by a building inspector or by the laboratory from blocks actually going into construction work.

TEST REQUIREMENTS.—Hollow cement blocks must be subjected to the following tests: Transverse, compression and absorption, and may be subject to the freezing and fire tests, but the expense of conducting the freezing and fire tests will not be imposed upon the manufacturer of said blocks.

The test samples must represent the ordinary commercial product, of the regular size and shape used in construction. The samples may be tested as soon as desired by the applicant, but in no case later than sixty days after manufacture.

Transverse Test. The modulus of rupture for concrete blocks at twenty-eight days must average 150, and must not fall below 100 in any case.

Compression Test. The ultimate compressive strength at twenty-eight days must average one thousand (1,000) pounds per square inch, and must not fall below 700 in any case.

Absorption Test. The percentage of absorption (being the weight of water absorbed divided by the weight of the dry sample) must not average higher than 15 per cent, and must not exceed 22 per cent in any case.

CONDEMNED BLOCK.—Any and all blocks, samples of which, on being tested under the direction of the bureau of building inspection, fail to stand at

twenty-eight (28) days the tests required by this regulation, shall be marked "condemned" by the manufacturer or user and shall be destroyed.

CEMENT BRICK.—Cement brick may be used as a substitute for clay brick. They shall be made of one part cement to not exceeding four parts clean, sharp sand, or one part cement to not exceeding three parts clean, sharp sand and three parts broken stone or gravel passing the ½-inch and refused by the ¼-inch mesh sieve. In all other respects, cement brick must conform to the requirements of the foregoing specifications.

STANDARD METHOD OF TESTING.

METHOD OF TESTING.—1. All tests required for approval shall be made in some laboratory of recognized standing, under the supervision of the engineer of the bureau of building inspection or the architect or engineer in charge, or all of these. The manufacturer may be present or represented during said tests, if he so desires. Approval tests are made at the expense of the applicant.

2. For the purposes of the tests, at least twelve (12) samples or test pieces must be provided. Such samples must represent the ordinary commercial product and may be selected from stock by the bureau of building inspection, or in the absence of such a bureau, by the architect or engineer in charge.

In cases where the material is made and used in special shapes or forms, too large for testing in the ordinary machines, smaller sized specimens shall be used as may be directed.

3. In addition to the tests required for approval, the weight per cubic foot of the material must also be obtained and recorded.

4. Tests shall be made in series of at least three (3), except that in the fire tests a series of two (four samples) are sufficient.

Transverse tests shall be made on full-sized samples. Half samples may be used for the crushing, freezing and fire tests. The remaining samples are kept in reserve, in case duplicate or confirmatory tests be required. All samples must be marked for identification and comparison.

5. The transverse test shall be made as follows: The samples shall be placed flatwise on two rounded knife edge bearings set parallel 7 inches apart. A load is then applied on top, midway between the supports, and transmitted through a similar rounded knife edge, until the sample is ruptured. The modulus of rupture shall then be determined by multiplying the total breaking load in pounds by 21 (three times the distance between supports in inches) and then dividing the result thus obtained by twice the product of the width in inches by the square of the depth in inches. $R = \frac{3\,W\,I}{2\,b\,d^2}$ No allowance should be made in figuring the modulus of rupture for the hollow spaces.

6. The compression test shall be made as follows: Samples must be cut from blocks, so as to contain a full web section. The sample must be carefully measured, then bedded flatwise in plaster of paris, to secure a uniform bearing in the testing machine, and crushed. The total breaking load is then divided by the area in compression in square inches, no deduction to be made for hollow spaces; the area will be considered as the product of the width by the length.

7. The absorption test shall be made as follows: The sample is first thoroughly dried to a constant weight, at not to exceed 212° F. The weight must be carefully recorded. It is then placed in a pan or tray of water, face downward, immersing it to a depth of not less than two inches. It is again carefully weighed at the following periods: Thirty minutes, four hours, and forty-eight hours, respectively, from the time of immersion, being replaced in the water in each case as soon as the weight is taken. Its compressive strength, while still wet, is then determined at the end of the forty-eight hours period, in the manner specified in Section 6.

8. The freezing test shall be made as follows: The sample is immersed, as described in Section 7, for at least four hours, and then weighed. It is then placed in a freezing mixture or a refrigerator, or otherwise subjected to a temperature of less than 15° F. for at least twelve hours. It is then removed and placed in water, where it must remain for at least one hour, the temperature of which is at least 150° F. This operation is repeated ten (10) times, after which the sample is again weighed while still wet from the last thawing. Its crushing strength should then be determined, as called for in Section 6.

9. The fire test is made as follows: Two samples are placed in a cold furnace in which the temperature is gradually raised to 1700° F. The test piece must be subjected to this temperature for at least thirty minutes. One of the samples is then plunged into cold water (about 50° to 60° F.) and the results noted. The second sample is permitted to cool gradually in air, and the results noted.

10. The following requirements must be met to secure an acceptance of the materials: The modulus of rupture for concrete blocks at twenty-eight days must average 150, and must not fall below 100 in any case. The ultimate compressive strength at twenty-eight days must average 1,000 pounds per square inch, and must not fall below 700 in any case. The percentage of absorption (being the weight of water absorbed divided by the weight of the dry sample) must not average higher than 15 per cent, and must not exceed 22 per cent in any case. The reduction of compressive strength must not be more than 33⅓ per cent, except that when the lower figure is still above 1,000 pounds per square inch, the loss in strength may be neglected. The freezing and thawing process must not cause a loss in weight greater than 10 per cent, nor a loss in strength of more than 33⅓ per cent, except that when the lower figure is still above 1,000 pounds per square inch, the loss in strength may be neglected. The fire test must not cause the material to disintegrate.

CONCRETE SPECIFICATIONS.

CEMENT—The cement may be any brand of American or foreign Portland cement which will meet the requirements of these specifications.

(NOTE—If the work is such that natural cement or Puzzolan, etc., cement may be used, they can be substituted in the above for Portland, or may be placed in addition to Portland, thus competing with it.)

CONDITION OF DELIVERY—It must be delivered in original packages, labeled with the brand and the name of the manufacturer. These packages

may be either barrels or bags, but must be well protected in either case from air and moisture. Any broken packages may be rejected or used at the option of the Engineer in charge of the work.

TIME OF DELIVERY—The contractor shall furnish the cement upon the work at least ten days before it is needed to be used, in order that time may be given to make the necessary tests.

HOUSING—It shall be stored in dry, well ventilated buildings for work of any magnitude, and for work of less importance it shall be safely stored and protected from moisture in any form.

TESTS OF CEMENT—The cement shall be tested in accordance with the specifications prepared by the American Society for Testing Materials, and the methods proposed by the American Society of Civil Engineers.

SAND—All sand used for mortar shall pass a No. 10 sieve, and 80 per cent of it shall be retained upon a No. 74 sieve. It shall be a silicious sand, as sharp as can be obtained within reasonable limits of cost. It shall be free from all vegetable and organic matter and shall not contain more than 10 per cent, by weight, of clayey or loamy material.

(NOTE—An addition of clay and (so-called) loam to sand has been found in many instances to produce an actual increase in strength. The supposition is that it is because of the voids being more perfectly filled than if the sand was clean and sharp. The specifications for the materials for concrete blocks prohibit clay or loam. The reason is that the evenness of color, so desirable in building blocks, is liable to be impaired if the aggregates are not perfectly clean.)

STONE—The aggregate shall consist of crushed trap rock, granite, hard limestone, or other material equally hard and durable which shall meet the approval of the Engineer. The broken stone shall be free from vegetable or organic matter in any shape and free from mud and dust or from lumps of clay or clay covered fragments. When sand is to be used in the concrete the stone shall be screened to pass through a ....inch ring and retained on a screen of ....inch apertures. The stone shall be thoroughly wet before mixing with the mortar. When it is desired to use screenings with the crushed stone the proper proportion of sand to be used shall be determined by analysis.

GRAVEL—Gravel shall be composed of clean pebbles of hard and durable stone, of sizes not exceeding two inches in diameter, free from clay and other impurities except sand. When containing sand in any considerable quantity the amount per unit of volume of gravel shall be determined accurately to admit of the proper proportion of sand being maintained in the concrete mixture.

CINDERS—Cinders used for concrete shall be from coal, reasonably free from sulphur, and shall contain no ashes or unconsumed coal, organic matter or clay or dirt of any description.

WATER—Water shall be clean and reasonably clear, free from sulphuric acid or strong alkalies.

MIXING BY HAND—(1) Tight platforms shall be provided of sufficient size to accommodate men and materials for the progressive and rapid mixing of at least two batches of concrete at the same time. Batches shall not exceed

one cubic yard each, and smaller batches are preferable, based upon a multiple of the number of sacks to the barrel.

(2) Spread the sand evenly upon the platform, then the cement upon the sand, and mix thoroughly until of an even color. Add all the water necessary to make a thin mortar and spread again; add the gravel (if used) and finally the broken stone, both of which, if dry, should be first thoroughly wet down. Turn the mass over with shovels or hoes, or both, until thoroughly incorporated and all the gravel and stone is covered with mortar; a minimum of four complete turnings is required.

(3) Another approved method, which may be permitted at the option of the Engineer in charge, is to spread the stone or gravel, or both if used, on the board as many inches in thickness as there are parts in the mixture. Over this place the sand evenly and on top of the sand the cement evenly over the whole. Turn the whole mass twice dry; turn it twice while applying water with a rose nozzle sprinkler, and give it a fifth turning when loading into the wheelbarrows or carts, or into the work.

MACHINE MIXING—Mixers used instead of hand work shall be batch mixers of the revolving drum type so arranged that the materials shall be placed in measured batches in the mixing receptacle and shall be discharged in thoroughly mixed batches. The minimum number of revolutions of the mixing drum shall be twelve for each batch.

CONSISTENCY—The concrete shall vary in consistency according to the requirements of the work. If mixed fairly dry it shall be tamped after depositing until the moisture flushes to the surface and the concrete quakes. The preferable consistensy shall be when the concrete is so moist that it quakes like jelly and requires very little tamping.

LAYING—(1) Each course should be left somewhat rough to insure bonding with the next course above; and if it be already set, shall be thoroughly cleaned and doused with all the water it will absorb readily before the next course is placed upon it. At the option of the Engineer the contractor may be required to treat the face of old work with an acid wash and put on an inch of retempered mortar before laying fresh concrete on it. The plane of courses shall be as nearly as possible at right angles to the line of pressure.

(2) An uncompleted course shall be left with a vertical joint where the work is stopped, and the concrete shall not be allowed to assume a slope.

(3) The work should be carried up in sections of convenient length and kept as nearly as possible on the same plane all over the work, and completed without intermission.

EXPANSION JOINTS—In exposed work expansion joints shall be provided at intervals of thirty to fifty feet. A temporary vertical form or partition of plank shall be set up and the section behind completed as though it were the end of the structure. The partition will be removed when the next section is begun and the new concrete placed against the old without any mortar flushing. Locks shall be provided if directed or called for by the plans.

(2) In reinforced concrete structures the length of the sections may be materially increased, or expansion joints may be entirely omitted, at the option of the Engineer.

DEPOSITING—Concrete shall be deposited within five minutes after it is mixed and shall be kept continuously mixed until deposited. No concrete

having attained an initial set shall be used, but retempered concrete may be used under the direction and personal supervision and instruction of the Engineer in charge.

FACING—Facing may be accomplished in one of two ways: (1) The material next the face may be spaded back with a flat shovel or flat fork, to permit the mortar to flow to the face; (2) about one inch of mortar as used in the concrete, but without the stone, shall be placed next the forms immediately in advance of the concrete. Either method may be used at the option of the Engineer, the contractor being permitted to use the least costly method that gives a satisfactory result.

FREEZING WEATHER—In freezing weather work may be proceeded with at the option of the Engineer in charge, provided that the water be warmed, but not boiled, the sand and other aggregates be heated, but not hot enough to blister the skin of the hand. On work where an efflorescence will not be objectionable, salt may be added to the warmed water in the following proportions: The difference in temperature between freezing point and the temperature likely to be encountered before the concrete sets shall be the amount of salt, expressed in percentage of the amount of water by weight, to be used. The salt shall be thoroughly dissolved in the water before mixing the concrete. Exposed concrete shall be covered with straw, hay, sawdust or cloth at night when the temperature is expected to drop below freezing point.

FORMS—(1) Forms shall be substantial and unyielding, properly braced or tied together by means of wire or rods.

(2) The material used on faces shall be of dressed lumber and on the backings may be of undressed lumber, secured to the studding or uprights in horizontal lines.

(3) Planking once used in forms shall be cleaned before being used again.

(4) Face forms shall be coated with soft soap, or with crude oil, at the option of the Engineer in charge, to prevent concrete from adhering.

(5) In dry but not freezing weather the forms shall be drenched with water before the concrete is placed against them.

(6) On face work forms shall be made carefully to prevent leakage of water through them, and care shall be taken to prevent the formation of ridges or depressions showing the marks of the forms.

(7) The forms must remain in place at least forty-eight hours after all the concrete in that section has been placed, except that when a fairly dry mixture, well tamped, has been used, the forms may be removed earlier. In freezing weather they must remain until the concrete has had time to thoroughly set.

FINISHING—After forms are removed small cavities are to be pointed up and projections smoothed off. The entire face shall then be washed with mortar made of one part of cement to two parts of sand, mixed to the consistency of cream and applied with a whitewash brush.

Another rule for salt in freezing weather. Use 1 lb. in 18 gals. of water at 32° and add 1 oz. for each degree lower.

REINFORCED CONCRETE.

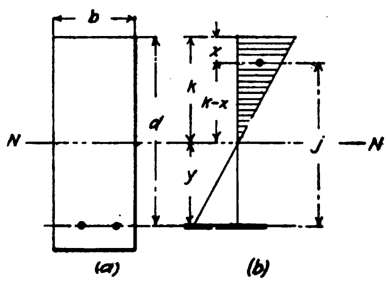
In preparing specifications for reinforced concrete the foregoing specifications for concrete work will do with the following points specially insisted upon:

1. No hand mixing allowed.
2. Specify kind and quality of steel.
3. Steel is to occupy exact positions called for in the detail drawings and must be wired together securely at all intersections.
4. The steel must be allowed to get rusty to an extent that will permit the loosening of mill scale, but all rust that is in scales must be cleaned off before the steel goes into the work.
5. When resuming work after a stop of more than half an hour all dead and half set concrete adhering to the steel and forms must be cleaned off, before beginning to pour the fresh concrete.

DESIGN.

Concrete being practically ten times as strong in compression as in tension a beam of plain concrete can only be used as stone would be used and cannot be depended upon to replace wood or metal because of its bulk.

Designing a beam by putting in the compression side a material strong in compression and in the tension side a material strong in tension meets the requirements whereby concrete can be used to advantage and reinforced concrete then is concrete reinforced in such a manner with steel that each material takes the stresses it is best adapted to resist.



Referring to the figures (a) and (b) the following nomenclature and symbols will be used to explain the design of reinforced concrete beams, etc.

As there is a plane in a beam where the fibers neither stretch or compress, termed the neutral axis, and as the tensile and compressive forces equate to zero at the neutral axis, it is important that its position be fixed in order to determine the exact fiber stress in the two materials.

After steel has passed the elastic limit it stretches rapidly and thus throws added stress on the concrete, so in reinforced concrete design we neglect the ultimate strength of the steel and base our design on the elastic limit. The fiber stress should never exceed one-third the elastic limit, which is usually six-tenths the ultimate strength.

Concrete has practically no elastic limit so we must consider the ultimate strength. The fiber stress should never exceed one-fourth the ultimate strength but building ordinances generally fix the fiber stress at from 500 to 600 lbs. per sq. in. for beams and not to exceed 350 to 500 lbs. per sq. in. for columns and struts.

The modulus of elasticity of a material is the force which, if such a thing were possible, would stretch it to twice its length, or compress it to zero. For steel it is taken at an average of 30,000,000 lbs. and the difference between the modulus of elasticity of high carbon and low carbon steel is so slight that it must be neglected in practical calculations.

Concrete has practically no modulus of elasticity but there is a practical ratio of deformation between concrete and steel that is termed the ratio between the moduli of elasticity and is designated by the letter n generally, but by some writers is termed e. The fact that the letter e is practically accepted by mathematicians the world over as representing the base of the Naperian logarithms, is an argument against it, whereas n stands for "number" and that is practically all it is in this connection for the number selected to represent the ratio, is arbitrarily chosen by some men.

In the greater number of building ordinances

$$n = 12 \text{ or } 15,$$

and the greater number of experiments thus far made indicate that these values are nearest the truth.

The amount of steel represented by A is the area in sq. ins. and is also represented by

$$p = \frac{A}{bd}$$

or the ratio of steel in the beam when b = width and d = depth of concrete above the center of the steel to the top of the beam.

N-N = neutral axis.

y = distance from neutral axis to center of steel.

k = distance from top face of beam to neutral axis.

$x = k/3$, for it is the distance from the compression face of the beam to the centroid of compression in the concrete.

j = moment arm, or distance from centroid of compression to center of steel.

The factors y, k, x and j are percentages of d and are always represented as decimals.

c = extreme fiber stress in the concrete and = 0 at the neutral axis.

f = unit fiber stress in the steel.

The position of the neutral axis is dependent upon the percentage of steel and the selected ratio of deformation. The percentage of steel is independent of the size of the beam.

For all practical purposes a beam is well designed when it has 1.25 per cent of steel ($=0.0125\ bd$) and the neutral axis is considered as in the middle. This gives a fiber stress in the concrete of 500 lbs.; in the steel of 10,000 lbs. and $n = 20$. A great many designers use this straight through on all their work and are certainly safe.

The fiber stress in the steel may be anything we wish to take but it must be remembered that the modulus of elasticity governs the deformation and if a high stress is used in the steel there is danger of lack of stiffness. That is if the beam is designed for steel having a fiber stress of say, 10,000 lbs. per sq. in. and we use instead a steel that can be stressed 16,000 lbs., the amount of steel cannot be reduced without lessening the stiffness of the beam and thus increasing the deflection.

The extension of the steel per unit of length is found by dividing the fiber stress by 30,000,000.

The value of a high carbon steel, or one that can be used with a high unit fiber stress is simply that when used in the same amount that a softer steel would be used, we obtain a high factor of safety, and if the concrete has attained a strength we did not figure on, then we have a much stronger beam to resist breaking loads. Within safe working stresses of course there is no difference.

The argument by which the size of a beam is obtained is as follows, assuming the neutral axis as in the middle.

The stresses and deformation in the materials vary as their distrances from the neutral axis so the compression in the concrete will be represented by the triangle in the upper half of the beam. To find the stress in the concrete assume that c, the extreme fiber stress is 500 lbs. per sq. in. and we have $\frac{bd}{2}=$ area of the concrete. Multiply by 500 lbs. and as the average stress is required and the area is triangular this must be again divided by 2, and the whole operation can be represented, as,

$500\,\frac{bd}{2}=125bd$ which represents the total compression, C, in the concrete side of the beam.

This must be resisted by an equal tension T, in the steel. Representing the area of the steel by A in sq. ins. and the area of the concrete by bd, in sq. ins. and assuming a fiber stress of 10,000 lbs. per sq. in. in the steel, we have

$$125bd=10{,}000\,A,$$

$$\text{or } \frac{A}{bd}=\frac{125}{10{,}000}=1.25 \text{ per cent.}$$

If other percentages of steel are used then it is necessary to find the exact position of the neutral axis and here we need "n". After the neutral axis is located "n" is no longer required.

The formula for the position of the neutral axis for any percentage of steel, with any assumed value of "n", is,

Values of k.

Area of steel $=p$	$\frac{E_s}{E_c}=n$				
	8	10	12	15	20
.005	.25	.27	.29	.32	.35
.006	.27	.29	.31	.34	.38
.007	.28	.31	.33	.36	.41
.008	.30	.33	.35	.38	.43
.009	.31	.34	.37	.40	.45
.01	.33	.36	.38	.42	.46
.0125	.36	.39	.42	.45	.50
.015	.38	.42	.45	.48	.53

$$k = \sqrt{(2pn + p^2n^2)} - pn$$

and for convenience a table should be calculated once for all, for every percentage from .003 to .2 for all values of "n" in ordinary use.

The following factors can be used for all percentages below one percent, giving the same results to two places decimal as the above formula:

$n=$ 8	$k=15+.18p$
10	$18+.18p$
12	$20+18p$
15	$23+.18p$
20	$26+.18p$

Values of k.

Area of steel $=p$	$f=10000$ Values of c.				$f=12500$ Values of c.				$f=15000$ Values of c.			
	500	600	700	800	500	600	700	800	500	600	700	800
.005	.20	.17	.14	.13	.25	.21	.18	.16	.30	.25	.21	.19
.006	.24	.20	.17	.15	.30	.25	.21	.19	.36	.30	.26	.23
.007	.28	.23	.20	.18	.35	.29	.25	.22	.42	.35	.30	.26
.008	.32	.27	.23	.20	.40	.33	.29	.25	.48	.40	.34	.30
.009	.36	.30	.26	.23	.46	.38	.33	.29	.54	.45	.39	.34
.01	.40	.33	.29	.25	.50	.42	.36	.31	.60	.50	.43	.38
.0125	.50	.42	.36	.31	.63	.52	.45	.39	.75	.63	.54	.47
.015	.60	.50	.43	.38	.75	.63	.54	.47	.90	.75	.64	.56

Area of steel $=p$	$f=16000$ Values of c.				$f=18000$ Values of c.				$f=20000$ Values of c.			
	500	600	700	800	500	600	700	800	500	600	700	800
.005	.32	.27	.23	.20	.36	.30	.26	.23	.40	.33	.29	.25
.006	.38	.32	.27	.24	.43	.36	.31	.27	.48	.40	.34	.30
.007	.45	.37	.32	.28	.51	.42	.36	.32	.56	.47	.40	.35
.008	.51	.43	.37	.32	.58	.48	.41	.36	.64	.53	.46	.40
.009	.58	.48	.41	.36	.65	.54	.46	.41	.72	.60	.52	.45
.01	.64	.53	.46	.40	.72	.60	.52	.45	.80	.67	.57	.50
.0125	.80	.67	.57	.50	.90	.75	.64	.56	...	.84	.72	.63
.015	.96	.80	.69	.60	...	.90	.77	.68	...	...	.86	.75

If the designer wishes to tie together the fiber stresses he purposes using and thus to determine the value of k, the following

formula is used:

$$k = \frac{2pf}{c}$$

With this formula a table should also be calculated for k, once for all and thus it will not be necessary to go through the process every time a beam is to be designed.

With these two tables calculated the manner of using them will be as follows: Suppose in a building ordinance the value of "n" is fixed and also the fiber stress in the concrete. Looking in the first table, giving values of "k", under the column headed by the given value of "n", find k. Then in the second table giving values of "k", look under the column headed by the given fiber stress in the concrete and opposite the value of k in that column will be the percentage of steel to use. The fiber stress in the steel will be tied to the concrete stress and can thus be found.

Values of Moment Factor K.

k	$\frac{1}{3}k$	j	Values of c			
			500	600	700	800
.25	.083	.917	57.3	68.8	80.2	91.7
.27	.09	.91	61.5	73.7	86.0	98.3
.28	.093	.907	63.5	76.1	88.8	101.5
.29	.097	.903	65.5	78.5	91.6	104.8
.30	.10	.90	67.5	81.0	94.5	108.0
.31	.103	.897	69.5	83.4	87.3	110.1
.32	.107	.893	71.5	85.7	100.0	114.1
.33	.11	.89	73.4	88.1	102.8	117.5
.34	.113	.887	75.3	90.5	105.3	120.5
.35	.117	.883	77.3	92.7	108.0	123.5
.36	.12	.88	79.2	95.0	110.9	126.8
.37	.123	.877	81.0	97.2	113.4	129.7
.38	.127	.873	83.0	99.5	116.0	132.7
.39	.13	.87	84.8	101.8	118.8	135.8
.40	.133	.867	86.7	104.0	121.4	138.8
.41	.137	.863	88.5	106.0	123.9	141.5
.42	.14	.86	90.3	108.3	126.3	144.4
.43	.143	.857	92.0	110.5	129.0	147.4
.45	.15	.85	95.6	114.8	134.0	153.0
.46	.153	.847	97.4	116.8	136.2	155.8
.48	.16	.84	100.8	120.9	141.0	161.0
.50	.167	.833	104.0	125.0	145.8	166.6
.53	.177	.823	109.0	130.9	152.8	174.5

The strength of a beam is given by the formula

$$M = Kbd^2$$

M being the bending moment in inch lbs.

All the dimensions being in inches,

$$d = \sqrt{\frac{M}{Kb}}$$

The concrete in the bottom of the beam below the steel is there simply for protection. It should never be less than the thickness of steel and for fire protection should never be less than two inches. As the steel is sometimes simply wire it is well to have a minimum thickness of one inch, so the steel can get a good grip, if fire protection is not considered.

To calculate a table giving values of K, use the following formula:

$$K = \tfrac{1}{2}cjk$$

and the table will have columns headed respectively by k, j, and different values of c.

To use the table first obtain the value of k and then under the column containing the chosen value of c will be found K.

The strength of a beam is fixed by the material deficient in area so one calculation is made for the strength as given by the concrete,

$$M = \tfrac{1}{2}cjk\ bd^2 = C$$

and for the strength as given by the steel

$$M = T = fpjbd^2$$

To design a beam, assume b as being equal to 1/20 the span and use the above formula to obtain d, or we can assume b, d, and either c or f and use either of the two last formulas, first finding k and j.

Given the size of a beam and the area of steel to find the fiber stress in the steel,

$$f = \frac{\frac{1}{2}ck}{p}$$

or, calling T the total tension in lbs.,

$$T = \frac{M}{jd} \text{ and } f = \frac{T}{A}$$

To find the fiber stress in the concrete,

$$c = \frac{2pf}{k}$$

A well proportioned beam will have the breadth from 1/20 to 1/24 the span and the depth from 1/10 to 1/12 the span.

This is for the reason that the upper part of the beam being in compression is in reality a slender column. When tied to a slab on top there is not so much necessity for this rule but it is best to be always conservative.

The best proportioned beam is one having a breadth not less than ½*d* and not exceeding ¾*d*. The rods selected should be of a size that the thickness or diameter will be practically 1/100 of the span. This for the reason that all rods should be imbedded in concrete for a length of not less than 50 diameters to insure bond.

It is a good plan to have stirrups in all beams and the stirrups should be bent like the letter U, passing under each rod in the bottom and up to within an inch of the top of the beam, then over and parallel with the top for about six inches. Mr. Ransome's empirical rule for stirrups was to have them of very heavy wire or ¼ inch rods and put four at each end of the beam vertically, on each rod. The first was placed at a distance from the end equal to ¼*d*; the second ½*d* from the first; the third ¾*d* from the second; the fourth a distance equal to *d* from the third. This in addition to bending up the rods.

For beams and girders we should always use the formula, $M = \frac{wl^2}{8}$ and not figure on continuity of action over supports, but as this action is present we should provide for it by turning up the bottom rods to go over the supports as soon as they get past the point in the bottom where they are needed for bending moment.

One method is to turn up one-third of the rods at the third spans on each side and let them go on a slant to the upper part of the beam at the end of the span and then over the support. Another method is to turn up one-fourth of the rods at the ¼ points, one-third of the remainder at the 1/6 points, ¼ of the remainder at the ⅛ points. The outside rods to go straight across in the bottom.

The steel in the top over the supports should be determined by the formula

$$M = \frac{wl^2}{12}$$

and in addition to the steel which has been bent up from the bottom

there should be other pieces going to the ¼ points and there bent down at an angle of 45 degrees to within an inch of the bottom.

Floor and roof slabs can be calculated by the formula

$$M = \frac{wl^2}{10}$$

when the panels are not square, using a width of 12 ins. as a unit. When the panels are exactly, or very nearly, square we can use the formula

$$M = \frac{wl^2}{20}$$

having the reinforcement run both ways, but adding to *d*, the thickness of the second layer of steel, in addition to the covering on the bottom required for protection and grip.

For stresses in the steel not exceeding 12,500 lbs. per sq. in. plain steel is all right. When the stress is higher the rods or bars should be deformed. All the patent systems in the market are good provided enough steel is used as determined by the foregoing formulas.

COLUMNS.

Columns reinforced with vertical rods are the best if economical designing is wanted and the column has to be designed for working stresses.

Let P = total load in pounds on column.

A = area in sq. ins. of column. To this however must be added an inch on each side for protection in case of fire.

c = unit fiber stress in concrete, usually 350 lbs., sometimes 500 lbs.

n = ratio of steel stress to concrete stress.

p = percentage of steel in cross sectional area of column.

then

$$P = Ac\,[1 + (n - 1)\,p]$$

The steel should be in smooth straight bars resting on steel plates at the bottom and wrapped with heavy wire having a pitch about equal to 12 or 15 times the thickness of the rods.

City building ordinances generally fix the area of the columns by requiring the thickness or diameter to be equal in inches to the height in feet. It becomes then simply a question of determining the amount of steel = p. Some economy may be effected by making the outside dimensions of the column conform to the ordinance

and compute the steel as for a column two inches smaller each way.

Steel in the form of spiral rods is used for column reinforcement but is expensive when the ordinances fix low stresses as above.

FOOTINGS.

Under a wall the footing is wide enough to distribute the pressure over an area it is believed is necessary for the ground on which it stands. Then for each 12 ins. in width of the wall (length of wall) the footing is figured as a cantilever beam projecting each side, the length being equal to the projection of the footing.

The steel runs straight across in the bottom, from one edge to the other. The amount of steel is figured from the bending moment. Stirrups must be used also.

At the outer edge there need be only a few inches of concrete over the steel. At the edges of the wall there is a share equal to one-half the total load and as we should not allow more than 50 lbs. per sq. in. shearing stress in the concrete the thickness of the slab at the junction with the wall will depend upon this.

In obtaining the bending moment on the two projecting cantilevers, each one carries half the load. This makes a short beam and care must be taken to use rods that will furnish sufficient bond surface in proportion to area.

Column footings are dimensioned by making them large enough to distribute the weight over sufficient area. For the reinforcement it is calculated as two beams, each as wide as the column, crossing at right angles under it. Each of these beams makes two cantilevers extending from the edge of the column to the edge of the slab and each of the four cantilever beams thus formed, carries one-fourth the load. The shear then on each edge of the column is equal to one-fourth the load.

Sometimes the reinforcement thus calculated is continued across the slab both ways, but in that case all the steel is not useful. Diagonal rods are sometimes used to the corners and sometimes rods are placed all round the edges.

CULVERTS.

Plain culverts are generally made square, with perhaps a dip in the middle to serve as a gutter in the bottom. The tops, floors and sides are calculated as slabs. Sometimes the floor is omitted

and the sides are retaining wall abutments, the top being a slab to carry the roadway.

DRY CONCRETED ROADBEDS.

Within the past year a number of street railway companies have constructed concrete roadbeds in a novel manner.

The concrete was mixed in the usual way but without water. It was therefore put in place exactly like dry ballast and tamped as ballast. In doing this it was found easier to tamp and line the ties and track.

After the roadbed is thus made a few rounds of a sprinkling car moistens the concrete and it sets gradually. In some cases no watering of the ballast was done but instead, the moisture that penetrated the ballast on account of rain, was found to be sufficient.

CHAPTER IX.

CONTRACTS AND SPECIFICATIONS.

It is unwise to attempt to do any work without plans and specifications being prepared in advance, with estimates of cost. Complete specifications are plain descriptions, with the necessary drawings, in detail, of the work to be done, and should form a part of the contract. Nothing should be taken for granted. Do not bind the contractor so he will lose control of his men and do not be too trustful in dealing with him. Use common sense.

As a rule it is better to do all public work by contract than day labor. It will be found most satisfactory in the end; although a very few places have found it otherwise.

It is not economical for the municipality to furnish paving and other material and contract simply for labor. In such cases inspectors are apt to be lenient in passing imperfect material in order to save loss. The only way is to have the contractor furnish everything under rigid inspection before it goes into place.

The council should not attempt to dictate to the contractor whom to employ and whom not to employ. It is not just to the contractor nor acting honestly with the people taxed for an improvement to compel the contractor to employ only home labor. It is well to help home labor and give it the preference, all things being equal, but if the contractor is limited to such help the cost of the work is increased. The men thus encouraged become independent and lazy and good men are scarce and hard to deal with. A contractor generally prefers to get all his labor in the town in which the work is being done, if he can. Special labor protection clauses as a rule are seldom needed.

For economical work there must be good, clear specifications, honest advertising and letting of contracts, with competent supervision and severe penalties for non-performance and shirking of work.

It too often happens that in small towns and cities contracts and specifications are copied from other cities where conditions require certain clauses. An unreasoning copying does not always work well.

Mr. Wait says there are four essentials to a contract. They are as follows:

1st—Two parties with capacity to contract.

2d—A lawful consideration; a something in exchange for its legal equivalent; a *quid pro quo.*

3d—A lawful subject matter, whether it be a promise, an act or a material object.

4th—Mutuality; a mutual assent, a mutual understanding, a meeting of the minds of the parties.

Without these four elements no contract is binding in law.

Dr. Waddell says: "The esentials of a well drawn contract that comes within the province of the engineer are as follows:

1.—A proper and customary form.

2.—A full and correct description of all parties to the argeement.

3.—A thorough and complete preamble.

4.—A statement of when and under what conditions the contract is to become operative.

5.—The limit, if any, for duration of contract.

6.—An exhaustive statement of what each party to the contract binds himself, his executors, administrators, successors, or assigns, to do or refrain from doing.

7.—A clearly defined enunciation of the consideration which each party is to receive; this is the essential *raison d'etre* of the instrument.

8.—The forecasting of all possible eventualities that would materially affect the agreement, and a full statement of everything that is to be done in case of each eventuality.

9.—Penalties for failure to comply with the various terms of the agreement.

10.—Provision for possible cancellation of contract.

11.—Provision for settlement of all business relations covered by the contract or resulting therefrom in case of cancellation, taking into account all possible important eventualities.

12.—Mention of the place where the agreement is drawn or of the place where it is to be put in force, so as to show the state under the laws of which the validity of the contract is to be determined, should suit be necessary to enforce it.

13.—Methods of payments, if any are to be made.

14.—Provision for extra compensation and the limitations connected therewith.

15.—Provision for possible changes in contract.

16.—Provision for transfer of the contract, or for subletting.

17.—Provision for settlement of disputes.

18.—Provision for satisfactory and sufficient bond, if any be needed.

19.—Provision for defense of lawsuits, if such provision be necessary.

20.—Definition of names used in contract, such as "Engineer," "Company," "Contractor" or "Trustee."

21.—Dating of contract.

22.—Proper signatures with the necessary seals, if the latter be required.

23.—Witnesses to the signatures, or execution before a notary public.

The American Public Works Association was formed in 1904. The object is to have a clear understanding of all that enters into a contract, between city officials and contractors for public work.

This association asks that the following rules be observed in preparing contracts and specifications:

1.—When state or municipal statutes conflict with association rules, the latter shall be waived.

2.—When work is done on a percentage basis, security should be given to guarantee estimate and faithful performance of the work.

3.—Designing engineer shall not compete for work advertised to be let under his plans and specifications.

4.—No bids shall be asked until money to pay for the work has been provided.

5.—Bids shall be opened and read in public.

6.—No bids shall be submitted after time named in advertisement.

7.—No bids shall be withdrawn after time set for opening of bids.

8.—Illegibility, or ambiguity, shall invalidate a bid.

9.—Bidders shall not be permitted to change prices stated in bid.

10.—Bids shall state specifically make of apparatus or machinery proposed, and same shall be specified in contract.

11.—When all bids are rejected new bids shall not be made on the same specifications without readvertising.

12.—The amount of certified check required shall be stated in advertisement calling for bids.

13.—Bid bonds may be substituted for certified checks.

14.—Checks or bid bonds shall be returned to all but successful bidder as soon as award of contract is made.

15.—Award of contract shall be made within thirty days after bids have been opened or checks returned to bidders.

16.—Bond shall not exceed 25 per cent of contract price.

17.—Twenty days shall be allowed contractor in which to furnish satisfactory bond.

18.—In event of discrepancies between the drawings and specifications, decision of the engineer shall be final.

19.—All instructions regarding work shall be given by the engineer or his assistants.

20.—Extra work shall only be done on written order of engineer when authorized by contractee at a price to be agreed upon.

21.—In deducting material not required only the value of same shall be deducted.

22.—Changes in construction shall not be made to lessen quantities of material in transit or in process of manufacture unless contractor be paid for all actual loss occasioned.

23.—When a specific make of machinery or apparatus is specified in contract same shall be furnished in accordance with manufacturer's plans and specifications submitted with bid.

24.—Engineer or his authorized assistants shall at all times have access to the work and materials for purpose of inspection, and have notice of concealed work before it is covered.

25.—In event of emergency work contractor shall notify engineer and engineer shall furnish inspector.

26.—Work done in regular progress of the contract and ordered torn down for purposes of inspection, if found to be in accordance with the specifications shall be at cost of contractee.

27.—Engineer shall give written notice to contractor when work or material has been rejected.

28.—Monthly estimate shall be made on or before the fifth day of each month.

29.—Monthly estimate shall be based on the contract price and shall include all material delivered and labor performed.

30.—Ten per cent of monthly estimate shall be retained by contractee until work is completed.

31.—Time shall be allowed contractor for delay caused by strikes, accidents, or other causes beyond his control.

32.—When work is completed engineer shall accept or reject same within a reasonable time.

33.—Contractor is released from all future responsibility when contractee takes possession of plant, whether settlement has been made or not, unless otherwise agreed.

34.—When work is accepted the 10 per cent retained shall be paid in final settlement, and bond shall be released and returned, except where a time guarantee has been agreed upon.

35.—Arbitration shall be resorted to in all cases before applying to the courts.

It will lengthen an already lengthy document too much to add the foregoing nineteen rules in the specifications and contract, so it will be enough to put in one paragraph, "Work to be done under the Rules of the American Public Works Association."

It will be a good idea also to put that statement in the advertisements for bids in order to attract the best contracting firms.

The above rules seemed to be necessary in view of the many absurd restrictions put upon contracting, especially in small places where the city attorney and city surveyor feel frightened over the prospect of having dealings with an outside man or firm.

Engineering News notes with approval the following clause from specifications sent to the editors for comment:

"The number of working days named in the proposal will be estimated in the comparisons of bids at the rate of five dollars ($5) per day."

In the first edition of this work the writer placed in this chapter specifications for all classes of work.

In the present edition the specifications have been placed in appropriate chapters, leaving in this only the matters not elsewhere discussed.

Every man having much to do with the preparation of plans and specifications and the drawing of contracts should have the following books which are placed according to price and also of relative value to men who are not lawyers.

Specifications and Contracts, by J. A. L. Waddell and John Cassan Wait.

Contracts and Specifications, by Prof. J. B. Johnson.

Law of Operations, and

Engineering and Architectural Jurisprudence, 2 vols., by John Cassan Wait.

The specifications presented here and elsewhere throughout the book were selected on account of their completeness and special fitness for the average place.

Every city and town engineer, however, should make a collection of specifications each year from the different large cities and be on the lookout for specifications for the kinds of work in which he is interested. This matter should be card indexed and kept where it can be readily referred to.

NATIONAL BOARD STANDARDS.

National Electrical Code, as recommended by the Underwriters' National Electrical Association, together with a list of electrical fittings.

Automatic Sprinkler Rules.

Underwriter Fire Pumps

Specifications for Hydrants.

Specifications for Water Pipes.

Specifications for Hose.

Fire Doors and Shutters.

Wire Glass and Framing of Same.

Watchmen's Clocks.

Signalling Systems

Fire Pails, Waste and Ash Cans.

Chemical Fire Extinguishers, both Hand and Stationary.

Fuel Oil Storage.

Kerosene Oil Systems.

Gasoline Lighting.

Gasoline Stoves.

Acetylene Gas Generators.

Gasoline Engines.

Any of the above standard specifications can be obtained from the National Board of Fire Underwriters, No. 32 Nassau street, New York City, upon application.

STRUCTURAL MATERIAL.

WROUGHT IRON—All wrought iron shall be uniform in character, fibrous, tough and ductile. It shall have an ultimate tensile resistance of not less than 48,000 pounds per square inch, and elastic limit of not less than 24,000 pounds per square inch, and an elongation of 20 per cent in eight inches when tested in small specimens.

STEEL—All structural steel shall have an ultimate tensile strength of from 54,000 to 64,000 pounds per square inch. Its elastic limit shall be not less than 32,000 pounds per square inch, and test specimens, ruptured in tension, must show a minimum elongation of not less than 20 per cent in eight inches. Rivet steel shall have an ultimate strength of from 50,000 to 58,000 pounds per square inch.

CAST STEEL—Shall be made of open hearth steel containing one-fourth to one-half per cent of carbon, not over eight hundredths of 1 per cent of phosphorus, and shall be practically free from blow holes.

CAST IRON—Shall be of good foundry mixture, producing a clean, tough, gray iron. Sample bars five feet long, one inch square, cast in sand molds, placed on supports four feet six inches apart, shall bear a central load of 450 pounds before breaking. Castings shall be free of serious blow holes, cinder spots and cold shuts. Ultimate tensile strength shall be not less than 16,000 pounds per square inch when tested in small specimens.

TIMBER—All timber used shall be of good, sound material, free from rot, large and loose knots, shakes, or any imperfection whereby the strength may be impaired, and to be of the size and dimensions called for in the specifications and plans.

OTHER MATERIALS—Hints as to proper specifications for brick, cement, sand, stone, etc., are to be found in the specifications in this book.

HYDRANTS, WATER PIPE, HOSE—To be in accordance with National Board standards, and latest edition of the New England Water Works Association.

GAS PIPE—To be in accordance with specifications of the American Gas Light Association.

CHAPTER X.

MISCELLANEOUS DATA.

LIGHTING.

The cost of street lighting does not seem to vary by any known rule. Investigation shows such wide differences in the same locality that sometimes hints of collusion between councilmen and officials of the light company may be warranted. The policy of the private company is of course to "charge all the traffic will bear," and as rates are often fixed by simple comparison of rates in near-by cities there is danger of innocent and unsuspecting men of honest intention being hoodwinked by showings from places where the administration of affairs is not so fair and honest as in their town. Yet there is also the danger of the lighting company being unintentionally wronged by a comparison unjust and too one-sided. But if the rates are fixed too low the company goes into the courts and shows its books whereupon the judge is liable to fix the rates. Owing to this some cities have a pleasant little way of fixing the rates at the point which is one notch higher than the litigation point and thereby secure a low-priced service—which is apt to be very costly in reality, considering service and breakages, or pretended breakages, or by the fixing of a schedule by the company which does not inure to the benefit of the city. No just comparison can be made without a full knowledge as to the number of hours of burning. A contract between the light company and the city should be specific and in detail and should be submitted to some man who has a knowledge of the business and the technical terms used, before it is signed. Claims of a lessening of cost under municipal ownership are not always borne out on investigation, as municipal book-keeping leaves much to be desired. Many men do not seem to consider that municipal works are as liable to deterioration by time as private works and therefore do not write off depreciation every year.

The invariable fault is to fall back on taxation to make up deficits, pay bonds, etc. While this is perhaps correct, the amounts the taxpayers have to pay on account of the bonds and other expenses incurred by reason of municipal ownership should show on the books of the plant as items of expense.

The cost of lighting with arc lights varies from $55 to $136 per year and the schedules and average hours of burning vary as much more. But it may be stated that in detailed examination of the schedules it does not show that the hours vary as the cost exactly.

For a small town kerosene lamps on posts have been used with only fair satisfaction, until a gas plant or electric plant has been put in. But it is not necessary to wait for a general plant to be put in as there are several makes of incandescent mantle gasoline lamps in the market which give excellent satisfaction. The burner has to be heated before the gas is lighted and some have a small separate alcohol lamp for the purpose while others have an attachment on the burner. The lamps are made in several styles for street use and many prefer them to gas or electric light.

From one of the circulars of a firm making gasoline incandescent mantle lamps the writer has taken a table showing the comparative cost of lighting a room 20x60 feet floor area and with ceiling of ordinary height. It is given below and has not been changed in any way. A few remarks might be made in this connection, however, as to the statement of cost so the reader can figure the matter out himself. A 16-candle power electric lamp is considered sufficient in most cases for a floor area of 100 square feet, therefore it is possible the cost of the electric light service might be less than the figures given. Three-fourths of a cent per hour is a usual charge.

A 16-candle power gas jet is more likely to consume 6 feet per hour, although the usual flow of an ordinary burner is 5 feet. One dollar per 1,000 feet of gas is cheap gas. The information as to cost of carbine for acetylene gas gives no information to the non-technical reader. In the city of Wabash, Ind., the cost of a 16-candle power acetylene jet in 1900 was 1/3 cent per hour with discounts off of from 10 per cent to 30 per cent for consumption of from 600 to 2,000 hours. The cost of the oil lamp with central draught, the writer believes to be a trifle low and he can not vouch in any

manner for the figures relating to the incandescent gasoline lamp, except to state that he knows where electric lights have been taken out and these lamps used instead, with better satisfaction and a remarkable saving in expense. The number of hours had best be investigated also in the table as the writer has not looked into it in any way except as to the cost explained above. It is always best to examine closely all tables and statements made in catalogues, as errors sometimes creep

COMPARATIVE COST.

For Lighting a Room 20x60 One Hundred Hours Per Month for One Year.

Eighteen incandescent electric lamps, 16-candle power, 288 candle-power, 21,600 hours at ¾ cent per hour, cost	$162.00
Eighteen gas jets, 16-candle power each, 288 candle power, 5 feet per hour, per jet at $1 per 1,000 feet, cost	108.00
Twelve Acetylene gas jets, 20-candle power each, 240-candle power, carbide at $90 per ton, cost	100.00
Three central draft oil lamps, 75-candle power each, 225-candle power, one gallon of oil per burner, 10 hours, at 6 cents, cost	21.60
Three incandescent gas lights, 100-candle power each, 300-candle power, one gallon of gasoline per burner, 60 hours, 6 cents, cost	3.60

The following table from the *Municipal Journal and Engineer*, June, 1905, was compiled by the Mayor of Syracuse, N. Y., from statistics gathered prior to the re-letting of the contract for that city:

City.	Population.	Municipal or Private Plant.	Cost Per Arc Light Per Year.	Fuel Used.	Average Price Coal.	Capitalization of Plant.
Albany	93,920	Private	$117.80	Coal		$2,000,000
Allegheny	138,018	Municipal	68.59	Coal	$1.88	
Atlanta	96,550	Private	75.00	Coal	2.50	
Baltimore	531,313	Private	99.92	Coal	3.20	2,700,000
Boston	594,618	Private	124.10	Coal		10,500,000
Bridgeport	77,635	Private	83.00	Coal		
Chicago	1,873,880	Municipal	75.00	Water		
Cincinnati	332,934	Private	96.00	Coal	3.75	700,000
Cleveland	414,950	Private	54.36	Coal	2.75	1,650,000
Columbus	135,487	Municipal	66.00	Coal	1.75	31,000,000
Dallas	44,159	Private	73.56	Coal	1.30	2,500,000
Denver	144,588	Private	54.36	Coal	2.75	1,650,000

City.	Population.	Municipal or Private Plant.	Cost Per Arc Light Per Year.	Fuel Used.	Average Price Coal.	Capitalization of Plant.
Detroit	309,653	Municipal	35.00	Coal	1.40	485,000
Elmira	37,106	Private	73.00	Coal	2.00	
Fall River	114,004	Private	90.00	Coal	3.00	3,250,000
Grand Rapids	91,630	Municipal	61.65	Coal	2.58	849,506
Hartford	87,863	Private	80.00	Coal	3.00	
Indianapolis	196,033	Private	109.50	Coal	4.15	350,000
Jersey City	219,462	Private	70.95	Coal	2.85	45,000
Kansas City	173,064	Private	70.00	Coal and water	4.00	1,900,000
Louisville	215,402	Private	74,00	Water		
Lowell	100,150	Private	97.50	Water		
Lynn	72,350	Private	65.00	Coal	3.00	
Memphis	113,669	Private	84.00	Coal		
Minneapolis	214,112	Private	120.45	Coal		
Nashville	82,711	Municipal	98.55			
New Bedford	68,955	Private	85.00			
New Haven	114,600	Private	94.00	Coal	5.00	
New Orleans	300,625	Private	45.00	Coal	1.79½	200,000
New York	3,766,139	Private	98.55	Coal		845,000
Omaha	113,361	Private	82.12½	Coal	3.75	1,000,000
Paterson	113,267	Private	77.00	Coal	3.25	
Portland, Ore.	98,655	Private	146.00	Coal		85,838,000
Providence	189,742	Private	94.50	Coal		
Reading	85,051	Private	101.00	Water		
Richmond	86,148	Private	63.60	Coal	3.80	6,000,000
Schenectady	43,538	Private	109.50	Coal	1.75	
Scranton	107,026	Private	85.00	Coal	2.91	
Seattle	92,020	Private	34.00	Water		
St. Joseph	110,479	Municipal	72.12	Coal	1.25	300,000
St. Paul	172,038	Private	66.00	Water		
St. Louis	612,279	Private	95.00	Coal	1.60	102,000
Toledo	145,901	Private	98.00	Coal	2.00	10,000,000
Trenton	76,766	Private	83.00	Coal	2.05	
Troy	75,567	Private	118.62	Water and coal		2,000,000
Utica	60,097	Private	116.18	Coal	2.50	2,000,000
Washington	293,217	Private	85.00	Coal	3.00	
Wilmington	81,300	Private		Coal	5.00	
Worcester	128,552	Private	108.00	Coal	4.75	600,000
Yonkers	52,701	Private	109.50	Coal		200,000

The cost for gas and electric lighting and for telephone service is not always lower in a large city than in a small one. It is apt to be more costly, for maintenance in a rapidly growing city or in one covering a large extent of territory is greater per service than in a steadily growing city of moderate size.

More is known about acetylene gas than was known a few years ago. Before any city determines upon gas or electricity or any other form of lighting to be owned as a municipal enterprise a long and careful investigation should be made and estimates obtained by a competent man, or by competent men.

In relation to the placing of lights a report made in St. Louis (1899) by the board of public improvements was against the use of

electric lights in the residence districts and in favor of incandescent mantle gas lamps (not gasoline, but city gas). The cost was found to be practically the same. In the business district a large volume of light, which will in some measure illuminate the buildings as well as the streets is needed, while in the residence districts an even distribution of light by small units is found to be wanted. Small units of light have an economical advantage for lighting long blocks with few street intersections. Incandescent electric lamps in the residence districts are objectionable on account of the wiring strung overhead and across intersecting streets, and electric arc lights in residence districts are an annoyance to the residents of the immediate vicinity. Trees in a residence district also interfere with a proper distribution of light from an electric lamp.

In many European cities the number of gas jets in out-of-the-way courts, narrow squalid streets and other places where in the United States it is thought a waste of good money to put lights, always attracts the attention of the traveler. Upon inquiring the reason he is told that one gas jet is equal to a policeman and very much cheaper, as a preventative of crime. In some cities of the United States it has been found that a bright light at each end of a block does more toward clearing a neighborhood of the unfortunate creatures of the half world than a nightly raid of the police.

FIRE AND POLICE ALARMS.

There is only one standard alarm system in the United States, and when a town becomes a city the agents for the system soon give all the information about it that any man can want.

It is too costly, however, for the small town, and for such places the writer has found the simple magneto telephone to be as efficient as anything and very cheap. The operation of such a system is as follows: The city is divided into districts, seldom exceeding six on account of the number of rings required, and each district has a number. As many telephones as the city can afford to pay for are put in locked boxes on poles with a notice painted on the box telling where the key may be found. In many of the saloons, stores, hotels and other public places and in the residences of the members of the fire department may be placed telephones or simply alarm bells. When any person notices a fire it is only necessary to go to the nearest telephone box, open it

and proceed to ring the number of rings which will indicate the district in which the fire is discovered. The alarm should be rung, say three times, and then the aurophone put to the ear so inquiries may be answered. They will come in at once from every telephone on the line and one answer is made to all, giving the exact locality of the fire by the house owner's name, or number and street.

The companies are supposed to have sufficient organization for every member to know exactly where to report. The chief should at once repair to the fire and the various captains and other designated officers to the places where the hose carts and ladder trucks and engines are housed. Some members who have apparatus at their residences or places of business proceed to the fire, while others whose duty it is will stop to rouse certain individuals who have no alarms.

BUILDING REGULATIONS.

The following extract from the 1904 report of the State Fire Marshal of Ohio is instructive:

FIRE LOSSES FROM GASOLINE EXPLOSION.

"The reckless use of gasoline in Ohio caused 395 fires during 1904; 396 in 1903; 473 in 1901. The many appalling accounts of persons being burned to death by explosions of this product of petroleum does not seem to have taught the people a proper appreciation of its power to destroy. They are, perhaps, not aware that the vapor arising from gasoline when mixed in a proportion of over 7 per cent with the air is one of the most dangerous explosives. The liability of powder to explode in handling is but slight if compared with that of gasoline.

"At the ordinary temperature of a dwelling, gasoline continually gives off inflammable vapor, and a light, a spark or a lighted cigar within a distance of ten feet from the material may ignite it through its vapor which explodes. The vapor from one pint of gasoline will, in the absence of free ventilation, make 200 cubic feet of air explosive. It depends upon the proportion of air and vapor whether it becomes a burning gas or an explosive. The danger does not lie so much in the devices for its use as in having it about. The widespread practice of using it for cleaning purposes is reckless indeed, for aside from its making the surrounding air

explosive the friction from rubbing textile fabrics in it may produce an electrical spark which will ignite it and set the room ablaze. A recent circular from the National Board of Fire Underwriters carries expert advice relative to the handling of gasoline devices."

The writer has prepared building ordinances for towns and intended in this chapter to present one as a guide. Not as a model ordinance, but one that would do as it has done in other places. The idea was given up when the Building Committee of the National Board of Fire Underwriters, New York City, made a final report. It is in the shape of a complete building code and designed to cover conditions in towns and villages as well as in cities.

A copy will be sent upon request, accompanied by ten cents postage, to all city officials. Perhaps others may also obtain copies, but that can be found out by writing to the Secretary in New York City.

The Code looks somewhat voluminous, but the writer would urge that it be passed in its entirety, for no one can foretell what the little place may become. There is nothing in it that will be likely to meet with more opposition than is common with ordinances prepared for the good of the many, with no hidden motives.

The passage of this ordinance in all the towns and cities of the United States will tend toward a desirable uniformity of insurance rates and a desirable uniformity in building construction generally.

When people herd together in thickly settled communities three things are to be guarded against:

Insanitary surroundings.

Risk of fire.

Risk of danger to life because of cheaply constructed buildings.

A good health department to care for the disposal of wastes will do much for the protection of health.

A good fire department is necessary and does much to avoid great losses by fire. A fire department, however, can be much less costly than it now is, if proper attention is paid to the erection of buildings. A poorly constructed building may cause incalculable damage by reason of being a fire trap. It also prevents the fire department doing good work because of fear that it may fall while

the fire is being fought. Firemen are brave and take great risks, but they are not going to take needless risks more than other men. A single badly built structure increases insurance rate for many blocks in its vicinity and lowers rents for as great a distance.

SOME DETAILS OF CITY BRIDGES.

(An abstract in *Engineering News* of a paper read by Willis Whited, assistant engineer, Department of Public Works, Pittsburg, Pa., and printed in the Proceedings of the Engineers' Society of Western Pennsylvania:)

City bridge floors should, wherever practicable, be paved, if the traffic is heavy enough to justify it. Plank floors are expensive to keep in repair, besides being rough and unsightly after they are somewhat worn; they are also apt to break through and injure horses' legs. A durable, cheap floor consists of reinforced concrete slabs placed on the stringers, or cross beams, and covered with asphalt paving. This is somewhat heavier than plank floor, and rather more expensive, but the cost of maintenance is so much less that in the long run it is more economical. It has the further advantage that it is waterproof and prevents the drainage from the roadway, which is quite corrosive, from rusting the steelwork underneath. Other good methods of constructing floors are by buckled plates, and by beams covered with flat plates; these, like the reinforced concrete slabs, can be covered with any suitable paving; they also furnish a better support for street rails if they are required.

If a plank floor is used, white oak or yellow pine are good for joists. The flooring may be laid in two thicknesses where the traffic is very heavy; the plank rots more quickly, but is not so apt to break through. If the traffic is light, a single thickness of plank is better and the plank should not generally be more than about 8 inches wide. I have so far been able to find no wood to compare with white oak for this purpose. Good white oak, however, is becoming very scarce in this part of the country.

For paving, asphalt can be used if there are no street car tracks and the grade does not exceed 4 or 5 per cent, and the traffic is heavy enough to keep the asphalt in good order. Asphalt being only 3 inches thick is lighter than any other paving. Some varieties of asphalt requiring no binder are only 2 inches thick (the binder being

1 inch thick). If asphalt paving is used where there are street car tracks it is generally best to put a row of stone blocks on each side of the rails.

Where the grade exceeds 4 or 5 per cent and the traffic is very heavy, block stone is, perhaps, the only suitable material. Where the traffic is light, brick may be used. Wood blocks, which are better if creosoted, make an excellent pavement where the grade is not too heavy; they are much lighter than brick or stone and about as durable. They will stand a very heavy traffic and can be used next to street rails. All these pavements should be laid on concrete foundations, which may be reinforced if required to be laid as slabs. Masonry bridges should, of course, be paved the same as ordinary streets.

The sidewalks may be built of white oak planks, which should be laid crosswise on the bridge and about ¼ inch apart, and should be dressed to uniform thickness. If the spaces between them are wider than ¼ inch people can see through them to the ground or water beneath, and some nervous people can not bear that. If the planks are laid lengthwise it is almost impossible to wheel a baby carriage across the bridge; besides, the ends lift up and people stumble over them. If plank sidewalks are laid, it is well to protect the curbs with steel angles, about 4x3x⅜ inches, with the 3-inch leg turned down to form the curb and the 4-inch leg horizontal on top of the sidewalk plank, and secured to it by ½-inch lag screws about 2 feet apart through the horizontal leg only. If they pass through the vertical leg, it is very difficult to get the curb angle loose to permit the putting in of new sidewalk planks owing to the fact that the screws rust firmly in the oak plank in a short time.

Cement is the best material for sidewalks with which I am acquainted. It can be laid as reinforced concrete slabs faced with mortar, or on buckled plates. Asphalt was formerly much used, but it is not so durable as cement, costs about as much, and, if any steel work comes up through, it contracts away from it, leaving a place where damp dust lodges and corrodes the steel work very rapidly. Cement, on the other hand, adheres closely to the steel and protects it from corrosion. If the sidewalk is of cement, which seldom occurs except where the roadway is paved, a cement curb is almost always the best. It is hardly ever necessary to face it with steel.

It is very important to thoroughly drain the spandrels of masonry bridges, especially where they cross over streets. They should be drained by means of pipes leading down through the piers into sewers. The backing of the arches should be made thoroughly waterproof, preferably by a coating of strong cement mortar; asphalt is not durable in such places, and any leakage or drainage through the haunches of an arch produces dirty icicles in the winter, and unsightly incrustations in summer.

(Note.—The writer wishes to say that he believes some preparation that sinks into the pores of the cement is better. He has used Szerelmey Stone Liquid for waterproofing and found it excellent. It is an English preparation, having been on the market fifty or more years.)

The railing of a bridge should be of sufficient height for protection, but not so high but that a person can readily see over it. It is sometimes well to incline it considerably inward at the top to prevent children from climbing over it, or it may be well to make the body of the railing of vertical parallel bars for the same reason. There should be no openings larger than about 6 inches wide, otherwise small children might crawl through. If a stone railing is built the same rule should be observed as to openings, and the projecting coping at the top will prevent children climbing over it; the inside should be dressed so as not to injure the clothing of pedestrians; it is well to finish the top with a slope of about 30 degrees so boys can not walk on it. All railings, of course, should be of tasteful design, and not only be, but also look, substantial. Although very often done, it is seldom necessary to put a railing on the curb line; its principal service there generally is to furnish a roosting place for loafers.

SURVEYS AND RESURVEYS.

Many of our towns have been settled so long and there has been so little care exercised in preserving monuments that the original stakes have disappeared and a "happy-go-lucky" way of establishing lines for fences and buildings has crept in which leads to trouble between neighbors. Sometimes the trouble flares out and the whole town is stirred from center to circumference over the matter and the merits and demerits of various surveyors discussed with acrimony. It is apt to get to such a pass that it is impossible

to relocate the original lines with certainty. The long:r such a state of affairs continues the worse the confusion and the prospect of costly law suits are promising at some future time when land has increased considerably in value.

The causes for such a state of affairs are many. Sometimes the original survey was faulty. This is often the case, for the original survey was made when land was cheap, with imperfect instruments and by careless methods; sometimes by men illy trained. When the original stakes disappeared surveyors coming after who were called upon to survey a lot had to start from some fence corner or building claimed to be correct by some and the correctness of which was denied by others. If these surveycrs had been commissioned to survey the whole town and their records kept carefully the troubles would not be so great. But the surveys were isolated ones made at a cost satisfactory to the lot owner and the price seldom large enough to enable a man to do all the work that was really necessary to do a correct job. When the owners between the later re-surveys finally get pinched there is trouble.

When the need of some proper definition of boundaries is realized and a complete re-survey decided upon, it should be made by a competent engineer who has had previous experience in that class of work and who has some legal knowledge. For his work must be done so if courts and juries follow over the lines they will say it has been as well done as it possibly could be. It is a risky think to disturb long established possession and only the most conscientious and careful work will do.

An axiom in settling disputes over lines is that monuments govern distances and distances govern bearings. Such decisions were given in former days when compass lines were so often run and there was known to be errors in that class of work. This setting of a monument was something any man could do and it was supposed almost any one could measure a line as he wished, but the turning of angles was a matter requiring skill and in matters of skill men often make mistakes. It is now conceded, however, that with the modern methods of laying out work the measuring of a line is a more skillful matter than the turning and reading of an angle and later decisions give the proper weight to both operations. Although there has been a change in that respect, there has been none respecting monuments and they must govern above every-

thing—unless positive proof can be given that they have been altered or changed in location. Of several calls in a description the certain govern the uncertain, even to the rejection of the uncertain. When a town has been laid off without any permanent monuments and the original stakes have rotted and disappeared the surveyor who comes in and tries to lay off that town mathematically without paying proper attention to long established possession is foolish. Each block has to be treated by itself and the surveyor must recognize what he terms inaccuracies. The city of course is entitled to the full street width, but it is doubtful if any buildings can be removed from the street if they are not an obstruction. They can be permitted to remain until they become a nuisance or until rebuilt, when the city can assert its claim to the portion of street they occupied. Rights never run against the public.

A re-survey made under such circumstances often gives crooked streets of varying width, where the original plat showed a straight street of even width, but if none of the points can be positively identified then it is impossible to lay the place off as it was claimed to be first laid off. The only way to prevent a recurrence of expense and trouble is to finally and definitely fix the lines by permanent monuments, well identified, and record the maps. If the town has been monumented and the buildings have been put up without surveys there is no doubt that they must come to the right lines, as the monuments govern, and if in existence at the time the buildings were erected there could be no excuse for not building exactly on the proper lines. Because the original owner was too stingy to employ a surveyor he should not be allowed to unsettle the lines of a whole neighborhood.

All subdivisions of land within the town limits should be subject to the approval of the Council before the plats are filed. The Council should prescribe the maximum and minimum grades, the direction of the lines and the width of the streets. When the owner submits his plats for the approval of the Council they should show proper connections with adjacent city monuments and show monuments at all street intersections and changes of direction. The elevation of all corners above city base should be also shown in red ink.

In laying out land into additions to cities it is common for streets to intersect so there are many triangular lots. These gore

lots should not be left to private ownership, for they are seldom built upon properly. There should be an ordinance passed providing that gore blocks shall have no lots with acute angles and that lots at the acute end of a gore block should have a frontage at the end of not less than twenty feet. The point thus cut off the lot to be added to the street intersection.

Such a provision will give the city a great deal of space that can be improved in a way that will enhance the appearance of the streets. The ordinance should provide also that the city can park or otherwise improve with statuary, fountains, etc., any part of the intersection space thus added to the natural intersection space made by the junction of the two streets. The ordinance should also provide that in districts where the roads are curved or practically laid out on contour grades that angular lots shall have no acute angles, but that where otherwise an acute angle would come the street lines of the intersecting streets shall be joined with a curve of twenty-five feet radius.

While some greedy land owners may object, the ultimate benefit is so great that it helps the value of the property.

The writer once prepared an ordinance for the governing of additions to towns and cities, but could not get the city council to adopt it. He believes it would be a good ordinance to adopt, for the rectangular system of street layouts has been overdone in the United States.

Every city should have a civic center and there should be radiating streets for convenience in going from one part of the city to the other as well as for beauty. In many places no improvements can be made in the layout, at an expense within the present reach of the people, but the laying out of additions to the city can be regulated and in future years when the city is rich enough to condemn property to make new streets and avenues there will be a comparatively small area to deal with.

ORDINANCE NO. ......

An Ordinance to Regulate the Subdivision of Lands within the Corporate Limits of .... and to Govern the Laying Out of New Additions to Said City.

The City Council of .... does ordain as follows:

SECTION 1. No street, alley, lane, avenue, thoroughfare or public highway shall hereafter be adopted to be placed upon the official maps of the City of .... or recognized as existent as other than a private thoroughfare in said City except the plat of such shall have been first submitted to the City Council of said City for adoption as a public street, lane, alley, avenue, thoroughfare or public highway and none shall be so adopted unless in the platting the sections of this ordinance hereinafter following shall have been fully complied with, and for reference all such shall be hereinafter designated as roads.

SECTION 2. All acre property within the corporate limits shall be and is subject to the requirements of this ordinance.

SECTION 3. No additions to said City now outside the present corporate limits shall be received within the corporate limits by extension of said limits to include same unless all roads therein conform to the requirements of this ordinance. Provided, however, that nothing herein contained shall prevent them being considered as private roads and omitted from all official maps and from all consideration in public improvements.

SECTION 4. No cuts shall exceed twenty feet in depth to allow roads to be constructed on a grade of five per cent and no fills shall exceed twenty feet to permit roads to be constructed on a grade of five per cent, except that cuts and fills on sidehill roads are not limited as to height and depth to permit roads to be constructed to a grade of five per cent.

SECTION 5. Where roads can be laid out on a maximum grade of five per cent and the depths of cuts and fills to obtain said grade shall not exceed ten feet the land shall be laid out on the rectangular system.

SECTION 6. Where the requirements of Section 5 can not be fully complied with the roads shall be laid out in the most practicable manner to accomplish the desired result as to maximum grade, which shall not exceed a limit to be fixed in each case by the City Council.

SECTION 7. Main roads shall be 100 feet wide and shall follow the section lines as nearly as

practicable, each section giving one-half of the said road.

SECTION 8. Secondary roads shall be not less than seventy feet wide and shall go through the centers of the sections as nearly as practicable.

SECTION 9. Only main and secondary roads shall be laid out on north and south and east and west lines, all other roads in the subdivision to be laid off at an angle of approximately forty-five degrees with said main and secondary roads.

SECTION 10. The subdivision of the property shall be made as though the main and secondary roads did not exist and shall be laid over same so that they shall be cut at an angle through the said subdivision. In the subdivision no roads shall be less than fifty feet wide and no alley shall be less than fifteen feet wide. There shall be an alley through the length of every block. No blocks shall be longer than seven hundred feet and the least depth of lots for building purposes between road and alley lines bounding same shall be one hundred and twenty-five feet.

SECTION 11. Where acute angles would occur by reason of the joining of two straight roads the angle shall be cut off and added to the road intersection by an isoceles triangle with a base for building front of twenty-five feet. Where two curved contour roads meet with an acute angle the side lines shall be joined with a circular curve having a radius of twenty-five feet, joining the said side lines on tangents, the additional space thus made being added to the said road intersection.

SECTION 12. When by reason of the joining of roads at acute angles the projection of the side lines would leave islands in the intersections having any frontage of less than fifty feet, said island shall be the property of the public to be added to the said road intersection or to be improved as a parking or place for statuary, but not for buildings having walls and roofs.

SECTION 13. When by reason of the laying out of main roads to a grade of not to exceed five per cent the connecting roads shall be wasteful of land if laid out on such a grade a departure may be made from the system upon express permission of the Council after a report upon said subdivision by the City Engineer. If necessary cross connecting roads may be laid out on steeper

grades provided they are of such width that a zig-zag roadway twenty feet wide may be constructed within said width with a grade not to exceed seven per cent.

SECTION 14. No main or secondary road shall have a grade to exceed five per cent, but shall be deflected where necessary in order to maintain that maximum within the limits of cut and fill provided in this ordinance.

Etc., etc., etc.

EVALUATION OF OLD PLANTS.

There comes a time in the history of almost every place when the idea of purchasing an existing plant has to be considered. At such a time the wisest course is to send for an outside competent man to make an estimate of the proper price to be paid.

There are three values to an old plant of a private company: First—The value to the company as an investment. Second—The value of the plant by reason of the material in it. Third—The value of the plant to the community. This third value may be nearly what the company places as the income producing value, and again, it may be far lower than the actual value of the material in the plant. The value to the community depends upon the efficiency of the plant. If it has been well designed and cared for and all extensions made have been under the direction and with the approval of the council, or board of public works, then the people may pay the price the company asks. Otherwise there is a serious economic loss possible by reason of the duplication of an already efficient machine. But if the plant has not been well designed and the extensions show that a niggardly policy has been pursued and there is evident a lack of judgment in the management of many of the small though important details it is possible the people have no system to purchase; it is simply a plant and a poor one. It may happen the plant can be taken at a proper valuation and remodeled to do all the work required of it at a less cost than an entirely new plant would cost. All these are matters to be determined at the time of examination.

The person employed to examine the plant has first to determine, as near as can be, the original cost. To this he must add the cost of all extensions. He must ascertain the exact indebted-

ness of the company and the state of the indebtedness. The yearly interest charge and cost of operation. The revenue from private consumers and the revenue from the city. The life of the franchise and the length of life left in all existing contracts, if any. And generally, the value of the plant to the community, the general features of design, the present condition, and cost of making it adequate to serve the town if purchased. The value of the material should also appear, but it is not of such importance as the other items. for the deterioration must be naturally an estimate for much of the plant.

With such information before them the people can act intelligently when it comes to voting on bonds. The embarrassing features of a purchase by the city are the value to place on any existing long term contracts the city may have with the company, and whether the city should pay anything for the franchise right, which has been obtained from the city. These questions require expert advice.

MUNICIPAL OWNERSHIP.

The writer has not changed his ideas on the subject of municipal ownership in the United States since he first declared himself thirteen years ago. In this book he does not intend to argue the question, for it has no place in such a book.

Municipal ownership of water works is almost a necessity, regardless of administrative defects, for the supply of water is then under absolute control of the citizens so long as they have any bonding ability left. A private company does not always afford the fire protection needed, although a fair showing of plants will possibly reveal that under private ownership there are more purification plants than under municipal ownership.

The hope of saving should not influence in the public ownership of waterworks, for sometimes it is so expensive a luxury that although taxes, interest and profits are not considered in the items of expense attendant upon operation, the people are extremely likely to pay more for their water than the private company charges.

In general the items of expense entering into the operation of a municipal plant will be the same as those entering into the operation of a private plant. However, it is not best to figure on any profit, for the business is a co-operative enterprise and the product

should be sold at cost. Taxes can not be figured in on a public plant, but insurance must be. The interest and sinking fund on the bonds should be charged as an item of expense, but no interest charged on the investment after the bonds are paid up. The money is permanently invested. It is not right either to figure into the cost of operation a fund to provide for future extensions. These will be met by the future residents when needed. As the noted Irish member of parliament said, "Do not be so careful to take care of posterity. It has done nothing for us and our grandfathers let us paddle our own canoe." Every thinking man realizes that it is not well to tax ourselves in this generation for the whole cost of an enterprise which will benefit the next generation as well.

It is proposed also that all annual extension work should be borne by general taxation, for there is a good return to the city at large and the amount needed is difficult to estimate in figuring up expenses of operation for the succeeding year in order to fix charges.

So then we have to consider as legitimate cost of running a municipal plant the interest and sinking fund to pay off the bonded indebtedness, the writing off each year of the depreciation, the making of repairs, the maintenance of the whole system and the cost of fuel, labor, administration, insurance, etc.

The revenue from the works should be from two sources; general taxation and private consumption. The consumers of the product should not pay the entire expense, for they are the pro gressive element whose property has been improved. The owners of unimproved property should pay a part of the cost. Every enterprise of a public nature in the town increases the value of all property and the unimproved property increases in value in a greater ratio than improved property. So if it is a lighting plant the city should pay for its own lights from general taxation and in case of a waterworks plant, for the water it uses or has a right to use.

This is the true theory at the bottom of hydrant rental and payment for water for public use when dealing with a private company. It is not right to make a contract at a flat rate with a water company for hydrants for a term of years. The council should annually get all the information regarding cost of the company's

plant, cost of operation and the revenue for the year past. Then fix the rates on an equitable basis for the consumers of water and guarantee to the water company a proper return on its investment by making up the deficiency by the payment of an annual sum on account of general benefit, fire protection and public use.

In return for this require the water company to put in hydrants whenever and wherever ordered by the city, the sum of money paid by the city being independent of the number of hydrants. The city should own the hydrants and pay for their erection, connection with the water mains and maintenance. It is a grave mistake to pay a certain sum per month or year for each hydrant, as it operates to keep many districts out of the reach of fire protection because of the increased cost of extra hydrants. Yet the people in these districts have their share of the taxes to pay for fire protection, general benefits and public use of water.

The tax rates in badly governed cities and also in cities owning all sorts of public utilities are high. Care must be taken that in owning public utilities the bonded indebtedness and the consequent tax rates do not become too much of a burden. In shifting from indirect to direct taxation there is not always economy. It may be that the opponents of municipal ownership on general principles may be correct and that wise laws well and intelligently enforced are better than municipal ownership.

FRANCHISES.

Upon the subject of municipal control volumes could be written. It is best for any small place having applications for franchises for street car lines, telephones, electric lighting, gas lighting, etc., to employ some competent person to prepare the terms on which the franchise will be granted and then advertise the franchise under these terms for sale to the highest bidder. The innumerable details can hardly be touched upon here, and new features become known daily.

SINKING FUNDS.

Two tables, or rather one table in two parts, here given, will help in the calculation of sinking funds.

TABLE III.

ANNUAL PAYMENT PER DOLLAR INVESTED, TO REPAY ORIGINAL OUTLAY AT THE END OF A GIVEN NUMBER OF YEARS.

Life of Plant. (years)	Rates of Interest on Installments—%.				
	3%	4%	5%	6%	8%
10	$ .08723	$ .08330	$ .07950	$ .07587	$ .06903
11	.07808	.07416	.07039	.06679	.06008
12	.07046	.06656	.06283	.05928	.05269
13	.06403	.06015	.05646	.05296	.04652
14	.05853	.05467	.05103	.04759	.04130
15	.05376	.04994	.04634	.04296	.03683
16	.04961	.04582	.04227	.03895	.03298
17	.04595	.04220	.03870	.03544	.02963
18	.04271	.03899	.03555	.03236	.02670
19	.03981	.03614	.03275	.02962	.02413
20	.03722	.03358	.03024	.02718	.02185

LIFE OF PLANT IN YEARS.

Deprecia-tion of plant.	Rates of Interest on Installments—%.				
	3%	4%	5%	6%	8%
1%	46.90	41.04	36.73	33.40	28.55
2	31 00	28.01	25.68	23.79	20.91
3	23 45	21.60	20 10	18.85	16.88
4	18 93	17.67	16.62	15.73	14.28
5	15 90	14.99	14.21	13.53	12.42
6	13 72	13.02	12.42	11.90	11.01
7	12.05	11.52	11.04	10.62	9.90
8	10.77	10.34	9 95	9.60	9 01
9	9.72	9.37	9.05	8.76	8.26
10	8.88	8.58	8 31	8.07	7.64
11	8 16	7.91	7.68	7.47	7.10

The first shows the annual payment per dollar invested to repay the original outlay at the end of a given number of years.

The following example shows how it is used. A given equipment of machinery, costing $25,000, is estimated to have a useful life of fourteen years. At the end of that time it will have a scrap value of $1,000. The money earned by the plant receives interest at 4 per cent, payable annually. What annual charge must be made to extinguish the principal by the time the machinery must be

renewed? The sum to be made up is \$25,000—\$1,000=\$24,000 in fourteen years. The first part of the table gives for fourteen years and 4 per cent, the payment \$0.5467 per dollar. The annual depreciation debit is, therefore, \$24,000x.05467=\$1,312.08. In addition to this, of course, interest must be paid on the \$25,000 investment; the rate of interest is not necessarily the same as the 4 per cent above used, since it depends on the conditions under which the capital was borrowed.

The second part of the table gives the term of amortization or "life of plant" for various percentages of depreciation and various rates of interest. The following example shows how it is used. A system of water pipes for city distribution cost \$125,000. Besides the interest on the bonds, the system is charged annually with \$2,500 (2 per cent) depreciation. In what time will the sum thus accumulated, earning 5 per cent interest, paid annually, be sufficient to pay for the bonds at par? From the second part of the table we find, for 2 per cent depreciation and 5 per cent interest, the figure 25.68 years. This represents the time required to wipe out the debt at par. If there has been, for example, a premium of 4 per cent paid, there requires to be paid back 104 per cent, and for this the table does not suffice directly. This part of the question is taken up in the chapter on Engineering Data, for it requires a knowledge of mathematics and the use of logarithms, so an engineer is a good person to call upon to figure the matter.

The tables are copied from those printed and distributed by Messrs. Charles C. Moore & Co., Engineers, of San Francisco, Cal., and printed in *Engineering News* March 2, 1905, from which the above descriptions of use were taken.

CHAPTER XI.

OFFICE SYSTEMS.

In the following chapter a method for keeping records and doing office work in small places is given. This present chapter describes systems in use in several offices of city engineers and engineers in private practice.

The following report printed in the Report of the Twenty-fifth and Twenty-sixth Annual Meetings of the Ohio Engineering Society is valuable:

REPORT OF COMMITTEE ON FILING AND INDEXING OFFICE RECORDS.

To the Officers and Members of the Ohio Society of Surveyors and Civil Engineers:

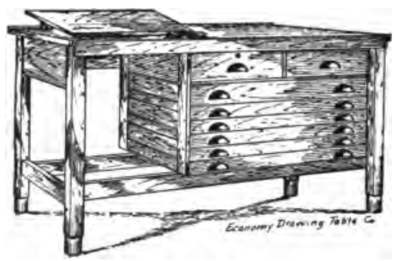
Gentlemen—Your Special Committee on Filing and Indexing plans, note-books, etc., beg leave to report as follows:

The chief object of a systematic method of filing and indexing office information is to afford those connected with the office a quick and certain means of consulting such information whenever it is needed. Simplicity is therefore one of the most important considerations.

The following description of the admirable system of filing and indexing plats, used in the City Engineer's office of Providence, R. I., was written by Mr. Otis F. Clapp and printed in the *Journal of the Association of Engineering Societies,* Vol. XIII (1894), page 561.

Every plan, as soon as it is made, or if its preparation is to take long, as soon as it is begun, is entered in a day book, in which the lines are numbered from 01 up. These day book numbers represent the total number of plans made in the office, of whatever kind, for whatever purpose, or by whatever department. The numbers are printed on the left hand side of the book. On the right the two pages are ruled in columns with the following headings: Drawer

and sheet number; title; made for; date; scale; kind of paper; size of sheet; field book and page; computation book and page; office number; field work by; platted by; drawn or copied by; receipted by; remarks. The last named column usually gives the day-book number of the plan copied from. Care is taken to have the first word of the description the most prominent word of the title, as the name of the street of which the plan forms a part, or the name by which the plan will be most easily recognized or thought of when wanted. Then follows a short and comprehensive description of what the plan represents, stating whether it is prepared for office use, or for what committee or purpose.



The assistant who indexes the plan, having first determined in what drawer it should be placed, gets from the engineer's clerk the "office number," which represents the number of plans actually on file in the office, regardless of departments, and also the last sheet number for the drawer in which he intends to file the plan. For this purpose the clerk keeps two books, one, called the "Index Drawer Number" book, containing the *sheet number* and *office number;* the other, called the "Index Office Number" book, containing the *office number, drawer number, sheet number* and *day book number* for each plan indexed, placed in the order of office numbers.

The clerk's duty is to keep the work posted up to date. If he does so, he can tell the last office or sheet number used in every drawer in the office, and thus prevent the duplicating of numbers, which might happen if the last previously indexed should be missing from its place.

Having thus obtained the day book, office, drawer and sheet numbers, he proceeds to stamp the plan. Each department has what is called a "Department Stamp," and the clerk has one called the "Miscellaneous Department Stamp."

These stamps read: Providence, R. I., City Engineer's Office, ... Department, and each has a line for the date and one for the day book number. This stamp is placed at the upper right hand corner of the sheet.

Another stamp, called the Office Stamp, and containing the office number, drawer number and sheet number, is placed at the right hand lower corner of the sheet so as to be easily seen on opening a drawer.

The plan is next indexed in the "Department Index," each department having an index for its own plans, giving the day book, drawer and sheet numbers, the title or name as entered in the day book, the kind of paper and the office number.

The engineer's clerk posts the entries from the day book into a "General Index" under the name used in the day book (a street name, if possible), thus collecting together information concerning the location, etc., of all plans made for whatever purpose on that street or under that name.

On the first day of January, 1905, 033552 day book numbers had been used, while on the same date the last office number used was 16,959. The difference of 16,593 represents the number of plans, copies, tracings or sketches made for committees or for construction, worn out or lost, etc.,

When a plan on file in the office is wanted outside of the office, the party taking it must sign a receipt for it, and this receipt is given up when the plan is returned. A record is also kept of such plans as are furnished and are not expected to be returned.

Hartford, Conn., and other eastern cities have adopted this system without change, and as it has stood the test of time in the city where it originated, there does not seem to be any need of changes. It is nearer perfection than any other system that I know.

The only criticism to be offered against it as used in Providence is the absence of the card index.

In Columbus we have found that the card index has become an almost indispensible adjunct to our system of filing plats and note-books. Book indexes outgrow themselves or wear out, and

have to be copied periodically, but the card index goes on forever, because it is elastic and little subject to wear.

All of our drawings are of standard sizes, being multiples of 7½ and 10 inches. All plats are laid flat in shallow drawers, designated by the letters of the alphabet. The drawers are 32x42 inches in size, and as many as necessary divided into compartments for sheets 7½x10, 10x15, 15x20 and 20x30.

The sheets in each drawer are numbered from 1 up. Generally 100 sheets in sets of 10, held in folded detail paper of the same size as the plats, are placed in each compartment, so that the number of plats filed in a drawer is equal to the number of compartments multiplied by 100.

The method of indexing does not materially differ from that used at Providence, but the day book is dispensed with, and each plat is indexed in the office index only.

Plats are cross-indexed under various heads, so that John Smith's private sewer in the alley west of High street, would be indexed under Smith, High street, and Wall street, the name of the alley west.

All improvements in alleys are indexed under the name of the nearest street *east* or *south* of the same, and if they have names they are indexed under these also.

When a plat is indexed under more than one head, sufficient notation is placed on each card, that all of the other cards can be readily found, so that when a plat is destroyed or lost, all of the cards can be withdrawn. Thus the card index is always up to date, without any dead timber, giving exactly what exists in the office at all times.

Field note books are numbered from 1 upward and filed in accessible cases. All books have index sheets inserted in the back, and the notes are indexed alphabetically when the book is full. The notes are also indexed on the card system, so that the book and page number of any survey can be found without trouble.

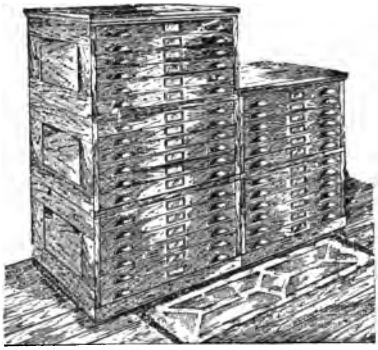
We are of the opinion that the Providence system of filing and indexing plats has no superior, and recommend its use in all engineers' offices, as it is comprehensive in its construction, yet simple in its application, and gives a complete history of every plat made, whether filed or not, and if filed, a certain means of finding it when wanted.

F. A. KEMMLER,
Chairman Committee on Filing and Indexing.

In the same volume of proceedings Mr. W. H. Sieverling, city engineer of Springfield, Ohio, had the following to say about his method of keeping records:

I will briefly outline the system used in the Engineering Department of the City of Springfield, Ohio.

For convenience sake, I will divide and describe the subject under four distinctive heads, viz:



ECONOMY SECTIONAL FILING CASE AS IT BUILDS UP.

First—Filing and indexing of correspondence.

Second—Filing and indexing reports, surveys, notes, deed descriptions, etc.

Third—Filing and indexing maps.

Fourth—Filing and indexing field books.

CORRESPONDENCE.

All correspondence received that bears on a certain subject and is of sufficient importance to keep, is given a file number. This number appears on all the correspondence relating to this subject. For instance, letters containing quotations or important information, concerning the building of a bridge on Fountain avenue across Buck creek, are received from the King Bridge Company, the Canton Bridge Company and the Toledo Bridge Company. They are given a file number, say No. 250, and recorded in the index under the letter "B," as Bridge across Buck creek at Fountain avenue No. 250; under the letter "F" as Fountain avenue bridge across

Buck creek No. 250; under "C" as Canton Bridge Co., Fountain avenue bridge across Buck creek No. 250; under "K" as King Bridge Co., Fountain avenue bridge across Buck creek No. 250, and under "T" as Toledo Bridge Co., Fountain avenue bridge across Buck creek No. 250. In answering correspondence a carbon copy or second sheet is made of the letter. The typewritten letter is copied in an ordinary letter book by means of a copy press and indexed in its own index and the second sheet is attached to the correspondence received and placed in its proper file. Copying the letter in the copy book is another check on the index and a quick method of finding all the correspondence pertaining to the given subject, as each letter contains the file number and it is only necessary to ascertain this number and take down the given file. Individual files consist of a piece of tough and rather thick, plain, manila paper, about a quarter of an inch wider and about an inch and a half longer than a sheet of typewritten paper. The papers are placed on this sheet of paper and the extra length folded down across the top and all fastened together with any good fastener or pin. On this folded top margin is recorded the file number. These files are then placed in a large ordinary file box, having a front that lifts up on a cloth hinge. The numbered edges are toward the open end, so that by lifting the front and running the finger down along the front edges, the desired file is quickly found. Each large file box bears on its front a paster, showing the serial number of the files contained therein; thus 1 to 100; 100 to 175, etc. The index is an ordinary lettered index that can be bought anywhere, except that it has a removable cover and with lace bindings, so that loose leaves may be inserted from time to time.

REPORTS, SURVEY NOTES, DEED DESCRIPTIONS, ETC.

Reports, survey notes, deed descriptions, small survey tracings, etc., are folded and placed in flat, heavy paper files such as attorneys use in filing away court cases. Each file is numbered and properly and copiously indexed in a "Report, etc." index of the same style as is used in indexing correspondence. In order that they may be kept clean and not become scattered, they are then placed in a large pasteboard file box of the same length and breadth but of sufficient height to hold from ten to twenty-five or more smaller

files. Each file box bears on its front a paster showing the numbers contained therein.

FILING AND INDEXING MAPS.

All maps and plans should be kept clean, flat if possible, and free from creases and folds. On account of the varying sizes, it is a hard matter to provide cases with suitable size drawers. We have two flat top cases 56 inches wide by 40 inches deep by 42 inches high, each containing five drawers, size 52 by 36 inches by 3 inches deep and four drawers, size 22 inches by 36 inches by 3 inches deep. In the lower right hand corner of every map, plan or plat in a space of one and one-half by three inches, appears the following: Engineering Department; Springfield, Ohio; No...; Scale..; Date.....; Surveyed by ....; Drawn by ....; for uniformity's sake, a rubber stamp or stencil may be used. All plats that can be kept flat and are not too large are filed away in the drawers. Each drawer is lettered and bears a paster showing the letter and numbers of plats contained therein; thus "A" 1 to 80; "B" 80 to 190, etc. Plats and profiles that can not be filed in drawers are rolled up and placed in a wall case containing a number of compartments 7 inches high, 6 inches wide and 30 inches deep. One end of the wall case contains compartments 12 inches high, 10 inches wide and 60 inches deep, for very large plats. All plats bear a small paper tag 1x1½ inches, such as are used by merchants, having the number of the plat on one side and an abbreviation of the title on the other side. From 20 to 40 plats are placed in each pigeon hole. Each case is lettered and the compartments bear a paster as an aid for finding the desired number quickly and insuring its return to the proper compartment. The index is the same style as described heretofore and plats are indexed thus: Plan of Reservoir—Drawer A. No. 37 or Profile of Main Street Sewer, Case D. No. 125.

FILING AND INDEXING OF FIELD BOOKS.

Field books are numbered consecutively. It was the practice to keep transit books for surveys and level books for levels and grades. This necessitated carrying two books into the field and the practice has been discontinued. All survey notes and levels are recorded in a level book, as it is of a convenient size. The pages

of these books are all numbered. Field books and pages and the bench mark elevation are recorded on each plat. The index is of the same style as described heretofore.

The foregoing method of filing and indexing office records has been found satisfactory. In order, however, to make this or any other system successful, it must be kept strictly up to date.

In reply to an inquiry as to proper methods for keeping track of maps, etc., in the office of an engineer in private practice the writer and W. D. Sell of Charleston, W. Va., replied in *Engineering News* in March, 1906.

Mr. Sell's letter is here abridged: "In numbering and designating maps and plans the year, month and day are used for serial numbers, 50723 was completed July 23, 1905. These numbers are followed by letters. D is original drawing, T a tracing, M a finished map. In connection with these the letter X is used. Preceding them it indicates a copy made in the office from a source

outside the office; succeeding, a map made outside the office. Thus, 20706XT means a tracing made July 6, 1902, from a map supplied by John Doe; 41102DX means a map supplied and filed in the office, made by John Doe.

Over half the drawings are folded so as to be placed in legal cap filing boxes, on the back of which are the limiting numbers. On the lower right hand corner of each folded map is its number and in the lower left hand corner the reference words.

Maps that can not be folded and tracings kept for making prints are filed in cloth covered telescoping tubes. Three lengths are used, 36, 42 and 46 inch, which are lettered respectively A, B, to A2, B2, etc.; 2A, 2B to 2A2, 2B2, etc.; 3A, AB to 3A2, 3B2 etc. The diameters range from 2 to 6 inches. Each map filed in these tubes bears the letter of the tube in which it belongs. It also bears the full title of the finished drawing and words underscored indicating the cards under which it is indexed.

A card index is kept and a blank book to fit the card index drawer, in which latter the titles are entered chronologically, the same words being underscored. Some maps require but one reference, others more; usually it is the name of the party for whom the work was done and the location. Then sometimes there are special titles requiring indexing, such as Mine Maps, City Lots, Culverts, Foundations, etc. On the cards and in the book the references to the tubes are in pencil.

In the book index the titles are entered in pencil at the time the work is done, and the maps filed in the "unindexed" tube or file box. When time is convenient, and at not too long intervals, the cards are made out and filed, the penciling is inked, and the maps properly placed.

Each tube will hold a number of maps, but too many in one tube make it troublesome. About once a year the tubes are overhauled and many maps are folded and filed away in the boxes."

The writer gives here his own letter in full. It is believed the majority of men holding office as engineers in small cities and towns are engaged in private practice, the city work being incidental. The methods described in the communication to the paper can thus be useful to city engineers as well as private practitioners.

"It is useless to attempt to keep maps, notes and records, if

no method is adopted for finding them quickly. Usually they are wanted when time is pressing. The writer has solved the problem to his own satisfaction in the following manner:

The first thing to do is to provide for taking care of the papers after classification. The second is to avoid complex classification in the filing receptacles. The third is to provide an adequate index and do all the classifying there.

Some men have a mania—or develop one—for minute subdivision and classification and devise a system (so-called) that is burdensome and acts as a deterrent upon friends who see it in operation. Complex systems are soon abandoned unless the engineer is fortunate enough to be able to indulge in the luxury of a filing clerk. An ordinary office boy can not index the papers of an engineer.

DRAWINGS.

A sheet of paper 36 inches wide can be divided most economically by adhering to the following regular sizes of sheets, which are lettered to indicate the size: "A" sheets, 9x12 inches; "B" sheets, 12x18 inches; "C" sheets, 18x24 inches; "D" sheets, 24x36 inches. Sheets between these sizes are to be lettered to correspond, and to be filed, with sheets of the next larger size.

The sheets are to be filed by size in drawers or filing cases. They can also be filed in home made portfolios, and these can be hung on a wall or partition, or be placed on shelves.

Many drawings will have to be kept in rolls, for some will be too large to file conveniently in drawers and others have to be taken out of the office frequently. It is the practice of the writer to keep all drawings rolled up that go often outside of the office. The rolled drawings are kept in pasteboard cases. These can be purchased from any dealer in drawing materials, but local box factories will usually make them in dozen lots for a much lower price.

The rolled drawings are naturally divided into two classes:

(1) Drawings larger than 24x36 inches, and to which a letter can be given according to their width. The following are suggestive: "E" sheets are 30 inches wide and may be of any length, provided they are too long to be classified with "D" sheets; "F" sheets 36 inches wide; "G" sheets 42 inches; "H" sheets 48 inches,

etc., each letter being for sheets 6 inches or less wider than the next smaller sheet. The width of the sheet regulates the length of the filing tube or case.

(2) Drawings in use on some particular job and kept together until the job is completed are usually placed in tubes of smaller diameter than the regular tubes for convenience, and only one set is kept in a tube, a label being placed on the outside so it can be readily kept track of.

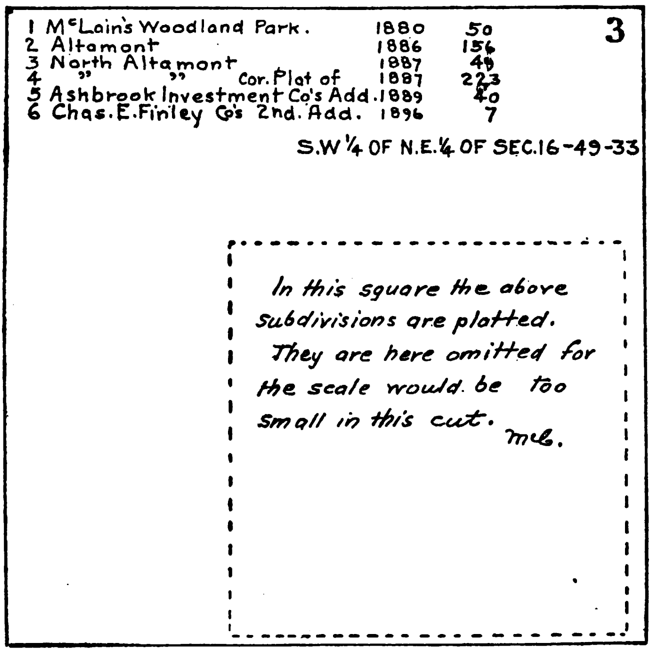


Fig. 1 40 Acre Plat.

The most satisfactory method for taking care of the tubes, considering economy and ease of reference, is to have a framework built in the office much like the studding in house framing. In each vertical post drive wooden pegs at a slight angle long enough to hold about two or three tubes on each peg. In order that prying

visitors may not become too interested in work going on in the office it is good practice to number every job consecutively and place only the number on the label pasted on the tubes containing work in hand.

The first class of drawings will usually be on paper or tracing cloth. The second class usually consists solely of blue prints. The second class will be indexed in the permanent index record, so far as the original drawings from which the prints are made are concerned. An additional index for work in hand is therefore a simple matter.

A book with plain pages and having an alphabetical index is used. Each job is numbered consecutively and a record entered in the book, commencing with the first page. Usually a page is given to each job.

First the number of the job is placed at the upper outside corner of the page. Underneath is placed the name and address of the party for whom the work is being done, and such other items (including dates) as may be considered necessary to keep the record compact and fairly complete. Below this put a list of the drawings used for the work, together with their index and filing numbers. In the aphabetical index forming part of the book it is simply necessary to put in the name of the employer (client), together with the job number and page of the record. The cost of the tubes is so small that it pays to keep all the drawings, together with specifications, contracts, etc., in these same tubes and file them away when the job is done. If any question afterward arises the ability to produce such papers when wanted is a valuable asset. The writer usually seals the tubes and puts them where the dust can not accumulate and where there will be small danger of fire.

An engineer should have a fireproof safe, or rather, a good sized vault, in his office and keep all the records in it. If he can not do this, but must carry them to a vault for storage each night, he will find rolls and flat portfolios better than shallow drawers and standard filing cases. Metal protected filing cases may, of course, be purchased if the engineer can afford it.

(NOTE—The writer wishes to add to the original letter by saying he uses shallow drawers in the office under the drawing board to hold plain sheets that have been cut ready for use and also to hold drawings referred to during the day. In a vault shallow drawers have a place. They should never hold more than twenty-five sheets, however, as it is a difficult

job to look for anything when there are more. The best device of this kind he has seen was one where there was a piece of heavy pasteboard as a false bottom. In the bottom of the drawer near the front was a large hole. When the drawer was pulled out the hand was pushed under the false bottom and it was raised and carried forward until the front rested on the top of the drawer thus permitting an easy examination of the sheets. Within the past few years a filing system has come into use whereby the drawings have eyelets attached to them on one side. A case is used with a door that comes down flat like a ladies' writing desk. Fastened to this door are two rods over which the eyelets go. When the door is swung to its vertical position the drawings hang by these rods and are very convenient for reference. Such a scheme requires little room.)

FIELD AND OFFICE BOOKS.

To avoid duplication of numbers all books used are numbered consecutively, transit books being indicated in the index by "T," level books by "L" and books used in the office by "O." The letter and number placed on the back, where it can be seen when the book is on a shelf, indicates to the searcher the book wanted.

(NOTE—The writer uses generally a book ruled in quarter-inch squares, or in ten squares to the inch, for all his work except work of a fairly regular kind, like railroad or canal surveys. There is no vertical ruling in red lines, so this enables him to use the book for all classes of work. If he happens to be so placed that he can not get hold of such a book he prefers to use a book ruled like a level book.)

Office books are two in kind. One kind is about the same in size as a field book, but costs much less, and when possible all pages should be ruled in squares. The other office books are usually about 8½ inches wide and 14 inches high. The pages are also ruled in squares. The squares may be eight or ten to the inch.

(NOTE—It should have been stated that the larger books are used altogether for structural work and static calculations. The smaller books for surveys, hydraulic calculations, etc. For figuring paper it is easy to purchase loose sheets for 20 cents a pound, ruled on both sides in quarter-inch squares.)

When doing any work it is wisest to do it in a book instead of on slips of paper to be thrown away. A slight degree of care used to indicate at the top of the page the work done thereon, and a careful indexing of the book will often save considerable annoyance and expense afterward. The writer, for this reason, when in the field prefers to do his figuring on pages of the field book rather than on separate pads; if it can not be done without interfering with the notes on an opposite page, then he figures in the back of the book.

In any scheme for indexing plats, etc., the letters "T," "L" and "O" are kept for the books. The books are not numbered with the number of the piece of work, for frequently one book may be

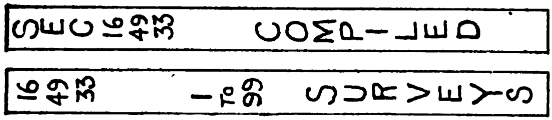


Fig 4 Title on back of Field Note Book and Section Book.

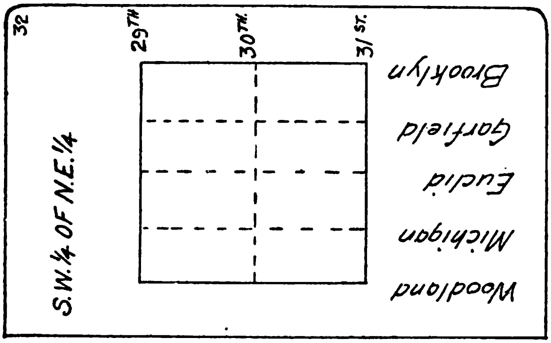


Fig. 3. Outline Sketch of Quarter Sec. in Sect. Book.

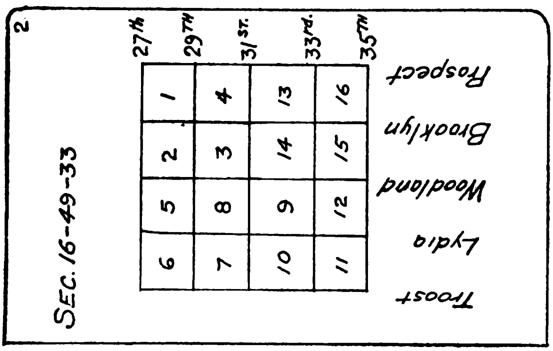


Fig. 2. Outline Sketch of Section in Section Book.

used on several jobs, and, conversely, some pieces of work will use up many books. It happens occasionally that one book may be used for both transit and level work. In that case it is filed as a transit book.

(NOTE—The writer is contemplating a change by omitting level books as a part of his scheme. Hereafter "T" will indicate field books, and "O" will indicate office books, for it is getting to be more and more the habit to use a book indiscriminately and he does so much stadia work that a general field book is used. If the book happens to have been used for level notes only, the word "Levels" can be put on the back edge.)

So far as the use of books is concerned, the writer prefers to have in books only data used or collected. For records he prefers loose sheets, 9x12 inches (or as much larger as may be found necessary, filed with the drawings). On these sheets can be platted all the information wanted in much better shape than it can be placed in a bound book. It helps, also, in making records, to be able to plat to scale, and this it is almost impossible to do in a bound book. The card index finds these sheets as quickly as it will find a book.

(NOTE—In a discussion on field books W. Newbrough, Evanston, Wyo., wrote to Engineering News a letter published May 18, 1905, describing his field books. His books are made to order, 4½x7 inches, on ruled paper, six squares to the inch, 80 leaves or 160 pages to the book, well bound, no other rulings. In connection he uses a 30 ct. rectangular plotting protractor, with the lower edge graduated six spaces to the inch. These he buys by the dozen.

He first numbers all the pages. At the top of the left hand page he writes the name of the work, who it is for, and other useful and necessary data. If the work is leveling, he draws column lines with a pencil; if it is a sketch he can make it somewhat to scale with little trouble. If a memorandum of pipe sizes or the address of a person in connection with the work, it all goes down. He writes on every line or every other line as he chooses, or makes an underground survey and keeps his notes entirely by sketching if he chooses. To illustrate, he gives as a sample the index page of Book 48, as follows:

Page.

1. Description of land sold by M. V. Morse to G. Anderson, 12-11-'03 (from deed).
3. Anderson's description of above from letter.
4. Sketch of Evanston No. 1 Reservoir.
5. Notes of Alignment for City Water Works change.
13. Notes of lines for City Water Works change.
33. Sketch standard coal car for K. C. Co.
35. Level notes for freeze-out ditch and alignment.
43. Calculations for above.
52. Calculations and stresses and sketches in truss for D. C. Co. coal dump.
76. Grade levels for Evanston, etc.

He adds that it is his rule to make all calculations in these books, even in the office. Compare this with the writers' method, already described, of numbering his books consecutively and of making calculations in books.

He gives field books their number when filled. The contents are card indexed in three or four ways, notably by name of person for whom the work was done, by name of work, and, if surveys, by township and range and by name of nearest postoffice. When going to make a survey in any locality he can easily look over the index and find books relating to surveys made there, and take the notes with him.

L. T. Haney, New York City, in the same issue, mentions his new field book with good binding on thinner paper than is customary, ruled with waterproof ink and having a protractor, graduated to five degrees, printed in faint ink on the right hand page to facilitate rapid sketching. The book is narrower than usual so it can be carried in the hip pocket. The writer does not favor the hip pocket, for perspiration is bad for the book and the skin may chafe on a hot day. He prefers a coat pocket, and if the weather is hot a light linen coat can be used. If he wears no coat then carry everything in a specially made leather pouch hanging from a strap over the shoulder. Such a pouch contains a loose pocket for table book, one for the field book, a place for a plumb bob and a pocket for pencils. For a protractor for field sketching he has found Almorth's Draftsman's Protractor very handy. It can be carried readily in the field book, and as it attaches to the paper by a needle point, good sketches can be made from any vertical or horizontal line as a meridian. Another useful little device of the same kind is called the Ready Draughting Instrument. It is on thin metal and a common pin can be stuck in the paper to serve as a center. Like the Almorth, it has a graduated edge in addition to a protractor graduation.)

PERMANENT CARD INDEX.

The permanent index is used for keeping track of field books, calculation books and drawings, maps, plans, sketches, etc. It is best to use for this purpose regular index cards, now so common a feature in office record systems. Cards 3x5 inches in a 120 division of the alphabet are very convenient. On this part of his outfit the engineer can go to any expense he wishes. The writer uses a cardboard filing box costing him 30 cents. His cards cost 8 cents per 100 and the alphabetical guide cards cost 80 cents per set. As the filing box was prepared only for filing cards it had no guide to maintain cards in an erect position when the box was partly filled. The guide, however, was an easy and inexpensive matter to arrange. The box will hold 1,500 cards in addition to the guide cards. The above figures are given to show that the cost of the index is not too high to prevent its use. The man who wishes to have a finely finished wooden case with trimmings can get it by paying the price.

Each job is indexed in the card index by the name of the

client. The full name is put at the top, together with the job number. On the lines beneath are placed the numbers of all the drawings, followed by an identifying description, precisely as in

CERTIFICATE OF SURVEY.

Kansas City, Mo. April 11, 1905

Mr. W. T. Alexander
Kansas City, Mo.

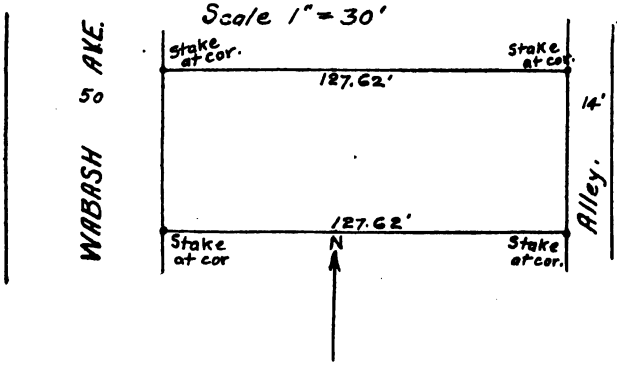
Dear Sir:

This is to certify that we have this date made survey of the premises described as Lot 8

Hazlecroft

and have marked the lines thereof in the manner represented on the accompanying plat.

Scale 1" = 30'



Yours respectfully.

Book 9-49-33 Page 77

Civil Engineers.

Fig. 5 Sample of Certificate of Survey "Plain Survey."

the reference book, for work in hand. This card also contains the numbers, etc., by which to identify the field and calculation books used on the work.

In addition to indexing by the name of the client it is indexed by the number in the same index. The number is placed at the upper left hand corner of the card and the name of the client is put underneath. Then for full information the searcher will look up the card containing the name of the client. All the data in field and office books and on plats and drawings is indexed by the name of the client, name of work, name of street, number of job, and, in fact, by as many cross references as the indexer cares to use. Bench marks, monuments and all survey points are indexed in the same way.

The writer prefers to use a single index instead of having one for each subject or class of work. It may be objected to that such a system as is here described lumps things too much, and it would facilitate matters to classify each subject in drawers or portfolios. The writer has seen many men abandon system altogether after making attempts at such a classification because it is hard to keep up and calls for too much indexing. In the system described the most economical methods, so far as space is concerned, are considered. It has been a matter of growth.

In the card index any degree of classification can be carried out. For example, cards can be headed Benches, Monuments, etc., and references made to streets and books and plats, to one or all. Waterworks, Sewerage, Street Improvements, etc., can be referred to also under a general heading and cross referenced as minutely as desired.

Whenever a drawing is traced or a copy given out, remarks can be written on the back of the sheet. Each tracing will carry the number of the drawing, and if the drawing was entirely on tracing cloth it is a good plan to put in the file with it a sheet attached to it by means of a clasp or pin. The sheet of paper should, of course, carry the same letter and number, so it can be put back in place if detached at any time the tracing is used. On this sheet should be put all remarks likely to be of value, such as dates when blue prints were made, to whom given, alterations, etc.

When drawings are changed so much that a new one is required, the new drawing should carry the old number and letter (if of the same size) and have on it memoranda to indicate the changes. The old drawing should be marked across the face in large letters, "Cancelled by drawing ......" By doing this all

drawings can be kept together without danger, as it is not good policy to throw such things away when replaced by new drawings. The writer has found it well sometimes to put old changed drawings away in tubes bearing the letter of the sheet size so that the flat files or drawers will not have too much old matter in them.

Sometimes for convenience on certain work a slight dropping into a decimal system of filing is adopted. Take, for example, a sewer system in Jonesboro. The drawings will be on sheets of different sizes, and in the upper left hand corner will appear perhaps as A 667, B 591, C 245, D 127 and the general map may be F 90. Underneath is the number of the job, the whole being in the form of a fraction. Pipe details will be No. 1 throughout for record purposes for that particular job. Manholes (general) will be No. 2. Manhole details will be 2.1, 2.2, 2.3, etc., and 2.21, etc., if there are details of details. Catch basins will be No. 3, Flush Tanks No. 4, etc. The reason for this is, that sometimes special records are made for each job, and besides, an engineer in the course of a long practice will accumulate standards. Of these standards he can have a special and separate index, and throughout he can give certain details definite recognition numbers. Such a matter can be best developed by the man using the system.

It is assumed that the index referred to relates solely to matter placed on sheets and to the accompanying data in books. It possesses an admirable flexibility and is capable, therefore, of an indefinite expansion. The engineer, however, has other things to preserve, such as memoranda and notes and fragmentary literature. Other indexes must be provided for them.

INDEX MAPS FOR CITY WORK.

When an engineer is doing considerable work in one city and needs to refer often to benches and survey points he can arrange in the following manner for keeping track of them. Procure a map of the city and divide it into spaces 4½x7 inches and give each space a number. Prepare cards of the same size, and on one side draw the part of the city in the space that card is to cover. Some engineers use a thin map by cutting it up and pasting the pieces on one side of the card. The map that is marked is the index and the cards are a record to take to the field.

When a bench is established, or a monument or a line point

set, a record should be made on a card in a card index box, or it can be entered alphabetically by streets in a book. All points should be numbered, one set being used for survey points and another for

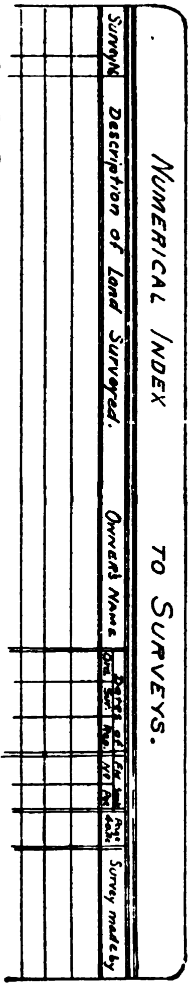


Fig. 7 Sample page of Numerical Index Book.

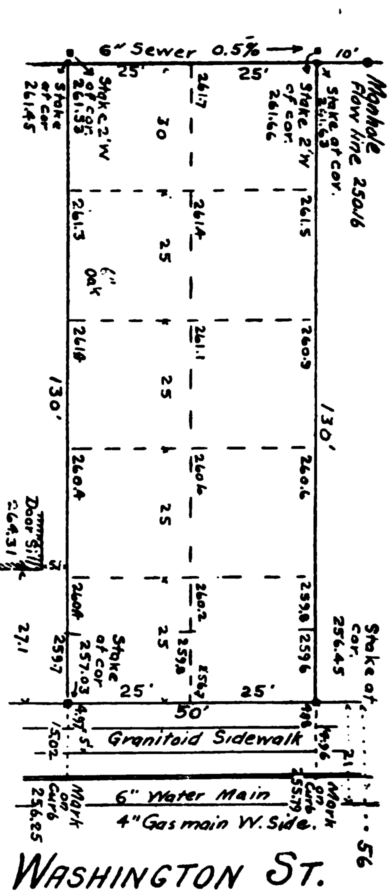


Fig. 6. Sample of Certificate of Survey, Plat of "Complete Survey."

benches. On the index map place the number in the proper location. On the small cards also put the numbers down in the proper locations. Red ink is generally used for elevations and some other color for survey points. On the back of the card write the description, exact location and elevation. The cards are filed in large envelopes in a box serially. When a survey is to be made in any part of the city a glance at the map on the wall gives the number of the card covering that part.

The card is removed from the case or envelope and placed in the back of the field book. This renders it unnecessary to do any copying when in a hurry. As the same information is on a card in a regular card index there is no danger of serious loss if the map card is lost while in the field.

LOOSE LEAF INDEX SYSTEM FOR NOTES, ETC.

In the course of time sketches, notes of observation, trade secrets, useful wrinkles and formulas accumulate and should be so preserved that they will be immediately available when wanted. It is a good plan to carry a loose leaf book with ruled pages and make such memoranda and notes on the loose sheets. Each item should be placed under a heading, so it can be found with certainty when wanted, and it is a good plan to put at the top of the sheet all the headings under which the subject will be looked for when wanted.

When back in the office the sheets should be taken from the covers and filed alphabetically in a box of the proper size. Where several headings are indicated, make out blank sheets for each subject, containing that subject at the top and underneath a statement as to the heading under which the information is filed. These auxiliary sheets are to be filed alphabetically.

It can be readily seen that such a system is self-indexing and calls for no additional work in recording, provided only one subject is entered on each page. The engineer has thus a constantly expanding self-indexed hand-book of data. It is, of course, not one he can carry with him in his pocket, but it is one he can easily refer to in the office.

TRADE LITERATURE.

(In the last chapter the writer has placed a part of his article which relates to the filing and indexing of fragmentary literature. In that chapter

is a list of dealers in articles required by city officials and the list has been prepared in order that readers will know who can supply their wants. As all catalogues should be preserved for future reference the place for a description of filing methods seemed to be in such a chapter.)

EVERYTHING IN ITS PLACE.

The writer is strongly opposed to roll top desks, or desks containing more than one drawer, in an office. That is, in the office of an engineer having assistants. He prefers a flat top table with one shallow drawer, where the man using it can put pencils, etc. and where he can leave small things of his own at night. This table can have some shelves at one end on which to place things needed during the day, but everything can go to its place at night. A large metal cash box is convenient, and one can be placed on each table so that books, memoranda, etc., used during the day can be locked in that box and be put away for the night.

To keep the drawing boards and tables free from dust, and to protect papers tacked down. a linen or muslin cover should be hung over each every evening at quitting time."

The following article is re-printed entire from *Engineering News* of July 20, 1905, being a reprint from *The Transit,* published by the Engineering Society of the University of Iowa. All the illustrations have been redrawn for this book.

METHODS OF FILING RECORDS IN A CITY SURVEYOR'S OFFICE.

BY FRED GABELMAN, C. E.

In some of our larger cities the lot and land line surveys are made by engineers in private practice, the city engineering department devoting its entire time to public improvements, doing nothing whatever with these surveys. Since no department of the public service is directly responsible for the maintenance of monuments, there is consequently no uniform system of monumenting street and other lines, hence every engineer or firm of engineers, doing this kind of work must have its own system of street and land line monuments and references to the same, which in fact is a very valuable part of the firm's assets.

If a firm has records of and references to all the section, land

and street monuments and lines in the city, and is called upon to make from three to twenty surveys per day, it must have these records and references very full and complete, and must have a very systematic and flexible method of indexing the accumulated and rapidly accumulating information in order that the preliminary notes for making any survey may be prepared quickly, and with the assurance that all the information which bears directly or indirectly upon the location of the tract of land to be surveyed is known and noted.

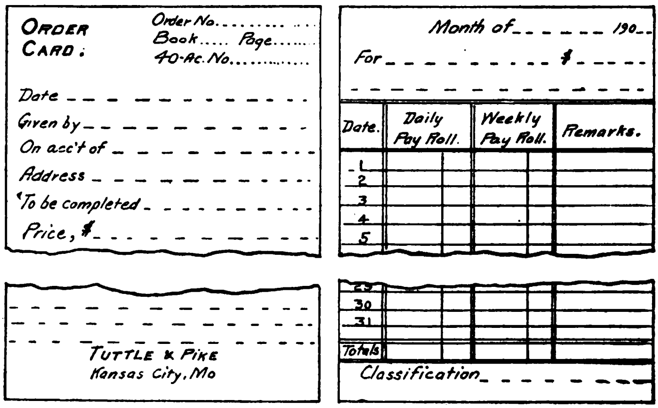


Fig. 8 Front of ORDER CARD. Fig. 9 Back of ORDER CARD.
(The cards used by the firm are printed.)

It was the writer's privilege to be associated with Tuttle & Pike, civil engineers of Kansas City, Mo., for eight years as chief draughtsman and as chief assistant, and while serving in this capacity the following system of filing records was largely developed, the writer being instrumental in the evolution of some of the principal features of the system. This system embraces the following records:

1. Recorded Plats.
2. Forty-Acre Plats.
3. Section Books.
4. Field Note Books.
5. Certificate of Surveys.

6. Miscellaneous Maps.
7. Bench Marks.

RECORDED PLATS.

Copies are made of all plats of record in the office of the Recorder of Deeds for Jackson County, Mo., the county in which Kansas City is located. These copies are made on tracing cloth and are exact copies of all the information on the original plats. They are all of a uniform size, the border line is 15x18½ inches and the trimming line is 16½x20 inches. The same letter is used in all the titles, thus securing uniformity for all plats. The plats made in each year are numbered in the order of their date of filing for record, the year being placed in the upper left hand corner of the plat and the numerical number for that year in the upper right hand corner.

The tracings are filed flat in drawers in a filing case in numerical order with reference to the year and year number. The years inclusive of the plats in each drawer are printed on the label card on the front of the drawer.

Copies are made of all plats that are filed for record each month, thus keeping the file up to date. "Positive" prints (that is, prints with white background and blue lines) are made of these plats as they are called for and sold to real estate firms, abstractors and others; quite a number being regular subscribers for prints of all plats filed for record.

For field and office use, positive prints, made on best linen paper, are used. They are folded uniformly so that they are 4x9½ inches. The title, section, township, range and 40-acre number are printed on one end, thus:

Beacon Hill
16 — 49 — 33
7

and filed numerically with reference to section number and 40-acre number in each section in a document filing case. The section numbers inclusive are printed on the label card on the front of each file.

FORTY-ACRE PLATS.

Plats are made on tracing cloth to the scale of 100 feet to the inch for each quarter quarter-section of all the sections within the

city limits of Kansas City, Mo., showing all the additions on same that are of record (see Fig. 1). The plats are 19½x20 inches. The addition names are arranged numerically with reference to date of record and printed in the upper left hand corner (the number to right of the year refers to the year number). The street names are put on the margin, and the lot numbers on the rear of the lots, so as to leave room for indexing surveys and for recording the measurements, angles and other information on the face of the plat. The plats are called "Forty-acre Plats." They are numbered from 1 to 16 for each section, as shown in Fig. 2. This makes the plats self-indexing, as one can find any quarter quarter-section in any section at once. The tracings are filed flat in drawers in a filing case in numerical order with reference to sections.

For office use positive prints are made on heavy parchment paper and bound with a loose leaf ring binder, so that at any time, as new subdivisions are made, they can be platted on the tracings and new prints inserted in the binder. There are three books. Each binder has four 1-inch rings. The surveys are indexed in red ink on these prints, also all measurements, angles, etc.

For field use positive prints are made on linen paper. These prints are duplicate copies of all field work compiled in the Forty-Acre record books in the office, so that the field man can see at a glance what has been done in the quarter quarter-section in which he is working.

SECTION BOOKS.

All references to section lines, land lines and street lines are compiled in field note books that are called "section books." There is one book for each section. Each book is divided into parts of ten pages each to correspond with the 40-acre plats of the section. The first ten pages are used for reference to section corners, quarter-section corners and measurements and angles between said corners. An outline sketch of the section is drawn on the second page (see Fig. 2), showing the 40-acre numbers, and the street names on the 40-acre lines, also measurements between 40-acre lines. The next 160 pages are used for reference and ties to street lines, ten pages being used for each 40-acre number, pages 11 to 20 for 40-acre No. 1, pages 21 to 30 for 40-acre No. 2, etc. This makes the book self-indexing as, for example, the ties to street lines in 40-acre

No. 4 would be on the pages in the 40's, ties to street lines in 40-acre No. 12 on the pages in the 120's, etc. The first page of each set

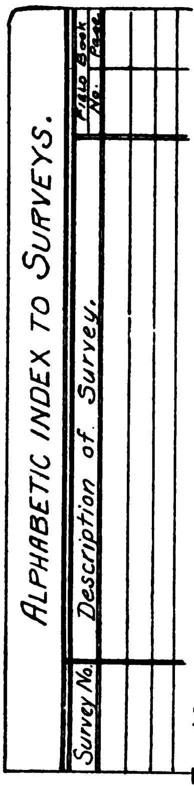


Fig. 10 Sample page of Alphabetical Index Book.

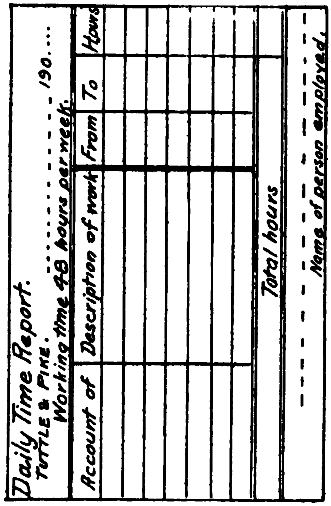


Fig. 12 Sample of Daily Time Report.

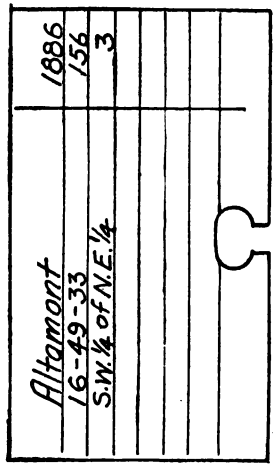


Fig. 11 Sample of Index Card for Recorded Plats.

of ten pages is used for general notes for that quarter quarter-section, such as block measurements, angles, etc. An outline sketch is drawn on the second page (see Fig. 3), showing the streets on the margin, the next eight pages are used for the reference and ties to the street lines, one page being used for each street. The street name is put at the top of the page, then the ties and references to the street lines. The streets are arranged from the north to the south, then from west to east. In a regular subdivision of a quarter quarter-section there are just eight streets, counting the streets on the margin, the east and west streets being on the 10-acre lines and the north and south streets on the 5-acre lines. In quarter quarter-sections that have more than eight streets, two streets are put on some of the pages.

FIELD NOTE BOOKS.

The field note books for lot and land surveys are arranged by sections also, so that the surveys in any section are all together in one or more books for that section. The books are numbered by the section. When more than one book is needed in a section the page number designates the book, thus: The first book is from pages 1 to 99, the second book from pages 100 to 199, etc. The pages are in pairs, that is, when the book is open the right hand page and the left hand page have the same page number. The information for the survey is laid out on the right hand page and the field notes as to just what was done are put on the left hand page. The arrangement of the information for the survey is as follows: Survey number, for whom survey is to be made, description of premises to be surveyed, what is required, and instructions to field party as to what to do.

The same style and size book, a Russia leather bound book, is used for both the field "section book" and the field note book. To distinguish the books the backs are lettered as in Fig. 4.

Profiles, cross sections and miscellaneous notes are kept in the ordinary level books, which are numbered numerically.

CERTIFICATE OF SURVEY.

When the survey is made, a certificate of survey is made up with a plat of the premises surveyed, showing just what was done.

In a "plain survey" (see Fig. 5) only the corners of the premises are marked. Very often the architect calls for what is known as a "complete survey" to furnish him the necessary data to design a proposed building for the premises. In complete surveys, the corners are marked, curbs marked, premises cross sectioned, buildings and trees, if any, located, face of adjacent buildings located with elevations of floors of same; also the established grade of street and alley, location and size of sewer with elevation of flow line, and location and size of gas and water mains are given. The grades, sewer, gas and water are compiled from the city records. See Fig. 6 for plat of "complete survey." The written matter is the same as for the "plain" survey.

When only the location of the building is required the written matter on the certificate of survey reads as follows:

"This is to certify that we have this date made survey of the premises

known as

No. 3018 Euclid avenue,

described as

Lot 136 Altamont,

and find the location of the building thereon to be as represented on the accompanying plat."

The certificates of surveys are 9½x16 inches. The original, which is sent to the client, is made on tracing cloth. A positive print (folded so that it is 4x9½ inches) is filed in numerical order in a document filing case. To assist in making the certificates of surveys a ruled form is made on heavy white paper and pasted on a small drawing board.

INDEXING SURVEYS.

As soon as the order for a survey is taken, it is indexed numerically in the numerical index book, and the survey number put on the upper right corner of the order card (see Fig. 8). A page of the numerical index book is shown in Fig. 7. When the survey is laid out the field note book and page is put on the upper right hand corner of the order card also. When the survey is made and note book sent back to the office the notes are checked carefully, the date when survey was made and by whom is put on the order card; also in the numerical index book with the book and

page. Then the note book is handed to a draughtsman, who makes up the certificate of survey and indexes it in red ink in the 40-acre plat book, also checks it off in red ink in the numerical index book. The index in the 40-acre plat book consists of date of survey, book and page, and survey number, thus:

April, 1905.
16 — 49 — 56
86755

(see also Fig. 1). When the report is ready to send to the client the final date is entered in the numerical index book and the upper part of the back of the order card is filled out (see Fig. 9). At the end of the month the time and expense is arranged on the back of the order cards, then they are arranged alphabetically with reference to clients' names and put in a cardboard envelope and filed numerically with reference to year and month in a filing case. The year and month is printed on the end of the envelope.

INDEXING MISCELLANEOUS SURVEYS.

Miscellaneous surveys, such as profiles, cross-sections, topography, etc., are indexed in the numerical index book the same as the lot and land survey, also on the order card, but instead of being indexed in the 40-acre plat book they are indexed alphabetically in the alphabetic index book (see Fig. 10). The surveys are classified into four classifications, namely: "Grading Estimates," "Profiles," "Sewers" and "Miscellaneous," and are indexed alphabetically under the proper classification. The alphabetic index book is a loose-leaf post binder book, and has an alphabetic side index back of each classification.

INDEXING RECORDED PLATS.

The card index system is used to index the recorded plats. They are indexed alphabetically back of alphabetic tab-cards. Each card contains the name of the addition, section, township, range, quarter quarter-section, year, year-number, and 40-acre number (see Fig. 11). The year and year-number aid to find the tracing of the addition, as it is filed numerically with reference to year and year-number. The section and 40-acre number aids to locate the addition in the 40-acre plat books, also to find the filed print of the addition.

INDEXING MISCELLANEOUS MAPS.

The miscellaneous maps are rolled and filed numerically in a filing case with drawers; fifty rolls are put in each drawer. The numbers inclusive are printed on the label card on the front of the drawer. These maps are indexed first in a numerical index book for maps and then alphabetically in the card index for maps.

BENCH MARKS.

The card index system is also used to file the bench marks for office use. Plain white cards are used; one bench mark is put on each card. The divisions in the drawer are defined by blue cards with a ¼-inch projection above the white cards, the projection extending one-third the width of the card. On these projections are printed the names of the streets on the 40-acre lines. The bench marks are arranged by streets that are on the east and west 40-acre lines. All the bench marks that are on a street on a 40-acre line and between this street and the street on the next 40-acre line south are arranged back of a blue card bearing that street name in the order of the north and south streets commencing on the west boundary line of the city and going toward the east. The arrangement of the east and west divisions commences on the north boundary line of the city and goes toward the south.

For field use the bench marks are put in a small loose-leaf ring binder book. The arrangement is the same as the card file in the office. Each field party has a bench-mark book.

Supplementing the foregoing article on city surveys the usual requirements of the architect as to surveys in Chicago, according to Mr. S. N. Howard, are as follows:

"Lines, grades, angles, location and elevation of sewer, elevation of walks in front of lot and adjoining the same and elevation of ground; and sometimes in addition is the size and location of water, gas and electric mains; the location of point where water, gas and electric service pipes come through the curb; location of house drains; the location, height and plumb of adjoining buildings; thickness of party walls at the several stories, and location and depth of the foundations of same."—Proc. Ill. Soc. Eng. and Surv.

The following description of a method to keep track of trade literature is from an article by the writer in Engineering News, March 8, 1906:

A description of filing and indexing methods for the office of an engineer (or for any business man today) would not be complete without reference to the preservation of trade literature. Some of it is of a high class and worthy of preservation and careful indexing.

The writer indexes by the name of the firm and by the principal articles mentioned. Some of the pamphlets are indexed by all the articles referred to and sometimes a copy is made of the index of the pamphlet or catalogue itself. The fulness of the index depends upon the character and probable future value of the publication.

A card index is provided for this material, which is entirely separate from all other indexes used in the office. Filing cases are used of the right size to take the matter readily, and they are numbered consecutively. Each pamphlet or catalogue is given the number of the case it goes into, and underneath is a serial number which tells at a glance the number of pamphlets filed. While this latter is not absolutely essential, it adds to the convenience of reference to the publication, and it is also useful for statistical purposes.

It is well to put in these cases all fragmentary literature obtained from all sources, such as clippings from papers and magazines, occasional volumes of society proceedings, etc. Clippings are usually pasted on sheets of paper and put into envelopes. Sometimes they are pasted into scrap books, put on the shelves with the filing cases and numbered with them. Sometimes, when a letter filing case is used they are filed alphabetically in such a case. No separate classification is attempted. The trade literature is coming in every day, and one book contains so many items it is impossible to make a classification on the shelves. It is best and simplest to make it in an index.

Pamphlet filing cases can be purchased that look well on a shelf, being made with book-imitation backs. They cost from $3 to $4 per dozen. The writer has used pasteboard cases, made by paper boxmakers and bookbinders at a cost of from 15 to 20 cents each. They are 3 inches wide, 7 inches high, and at the open end are 11

inches long on the bottom and 7 inches long on top. The pamphlets therefore are on their edges.

For larger catalogues special sizes have to be made. The filing transfer cases made for the Shannon system of filing letters are very good when purchased without the attachments to which the letters are fastened when transferred. They consist of a case, open at one end, into which fits a piece of pasteboard, bent to form two sides and one end.

The writer has adopted, and intends holding to, cheap letter files that can be purchased in any stationery store for from 15 to 20 cents each. He prepares them by removing the index sheets, putting in a division of cigar box wood to make two filing spaces, and placing them like drawers in a case made for them. The inside dimensions are 10x12 inches, and putting a division in the middle gives two compartments a trifle less than 5 inches wide by 10 inches long. Every catalogue that will go into such a space is put there. Sometimes a little trimming of edge is necessary.

Generally the division is made so that one side will be 6½ or 7 inches wide by 10 inches long. The other side will take small catalogues. On the outside of the file is marked the width of the division, so the indexer can tell at a glance whether the catalogue he is indexing will go into a certain file. It can be seen that serially numbered publications do not follow in order in filing cases. When a case is filed a small letter "F" is put on the outside, under the number.

The odd sizes in which trade literature comes is a nuisance, but fortunately the large-sized publications, printed on extra heavy paper, seldom contain anything worthy of preservation. They seem to be gotten out to feed the pride of some one or other and to make a job for the printer. Such expensive work is thrown away, except in so far as it tends to develop the art of printing and engraving. Few publications having pages exceeding 9x12 inches contain data of any kind that is valuable. The small pocket sizes are often crammed with useful material.

CHAPTER XII.

CITY ENGINEER'S RECORDS.

The too common fault with the conduct of the office of town or city engineer in the small place is that records are poorly kept, or that there are no records worthy of the name.

Rather, it is a misfortune, not a fault, as the trader said of the blind horse. As the office is unfortunately a spoils place to be fought and scrambled for yearly, by men who should possess professional brotherly love; as the pay is poor; the bills are paid grudgingly and often cut down, there is little heart left in a man to lead him to keep good records for the benefit of his successor, who may have maligned him to secure the job.

Nevertheless he is a public officer and should keep complete records of all work done in his official capacity during his incumbency. If he walks out of office and retains notes, the lack of which will embarrass his successor, he is practically a thief.

It was once common for the retiring town or village engineer to retain his notes when he went out in order to sell copies to his successor. The writer knows of some places where that has been done within the past year or two.

All surveyors and engineers should give to their clients plats and records containing enough data to enable any competent man to review their work. The public is the client of the engineer who occupies a public position, and the only manner in which such a client can be served with the proper information is by filing it in archives for the information of the public for all time. In addition to maps and notes of surveys there should be complete plans, specifications, details and reports on public undertakings during the term of office of the retiring engineer.

The preceding chapter on filing systems contains many valuable hints on the preservation of matter of interest and value to engineers. They are not enough in detail—except for the splendid

paper of Mr. Gabelman—so the writer intends in this chapter to outline a method for the use of town and city surveyors and engineers.

When speaking of the left hand end of maps or drawings the end held in the left hand when examining them, is meant.

All sheets should have a border one inch from the edge, except that the border should be two inches from the left hand edge, to permit of binding. A good way to bind the maps until enough have been collected to bind in a proper cover, is to take a piece of heavy detail paper a little more than twice the length and an inch wider than the sheets. Fold this and through perforations in the left hand end of each sheet put brass fasteners. Do not put more than twenty-five sheets in any cover. The covers can be hung on the wall inside a cabinet that has a cover closing like a writing desk. This protects them from dust and when the cover is down it makes a table on which the maps can be examined. The writer has used such a filing case for a great many years. A firm of filing case manufacturers obtained patents on portable cases that are on the same general plan, but much better.

Cloth mounted paper is expensive. It is a real necessity in an office where the records are to be consulted for years, but many engineers can not afford to buy great rolls to cut up. For such men it is well enough to buy good drawing paper, white or buff, and mount it themselves.

The writer did that for many years. He does it yet occasionally when a frequently consulted plan or drawing on unmounted paper begins to show the need of care. The cloth can range from fairly open cheap bunting like butter cloth, to a heavy sheeting or the best of linen. The piece is to be cut somewhat larger than the piece of paper to be mounted and should be well wet and then squeezed until fairly dry. Spread it on a smooth table and put tacks around the edge about one inch apart. It is to be stretched tight. Immediately cover it with paste brushed on to fill the web. The back of the paper is then given a thin coating of paste and placed on the cloth. Put one edge down first and rub hard to press out all air bubbles. The other end is to be kept elevated and slowly lowered as the rubbing proceeds toward it. There should be no lumps of paste and it is absolutely necessary that there be no air caught underneath. Rub the edges down care-

fully and leave the room when the paper is stuck. Refrain from any additional handling or smoothing, no matter how badly it looks before it dries, and when dry it will be all right. It should be left at least twenty-four hours.

For duplicating drawings the blueprint process from tracings is, of course, the standard. It is not necessary to give here instructions for making blueprint paper, as it is so cheap and can be obtained everywhere. If the reader has never made blueprints there are numbers of cheap books on the market telling how.

Wherever possible the writer prefers to make his drawings in colors with transfer inks and reproduce them by the Hektograph process or by the clay process. This latter is a vast improvement on the hektograph and nearly all instrument dealers can supply the materials.

On all his detail work the writer uses sheets 8½x14 inches (specification sheet size), and draws all details carefully to scale in colors. As it is hard to scale from such reproduced drawings all dimensions are marked. The details then, instead of being on cumbrous sheets, can be bound in with the specifications.

For men who wish to use the hektograph, owing to the expense of the clay outfit, the following article from *The American Machinist* will be of interest:

HECTOGRAPH PRACTICE.

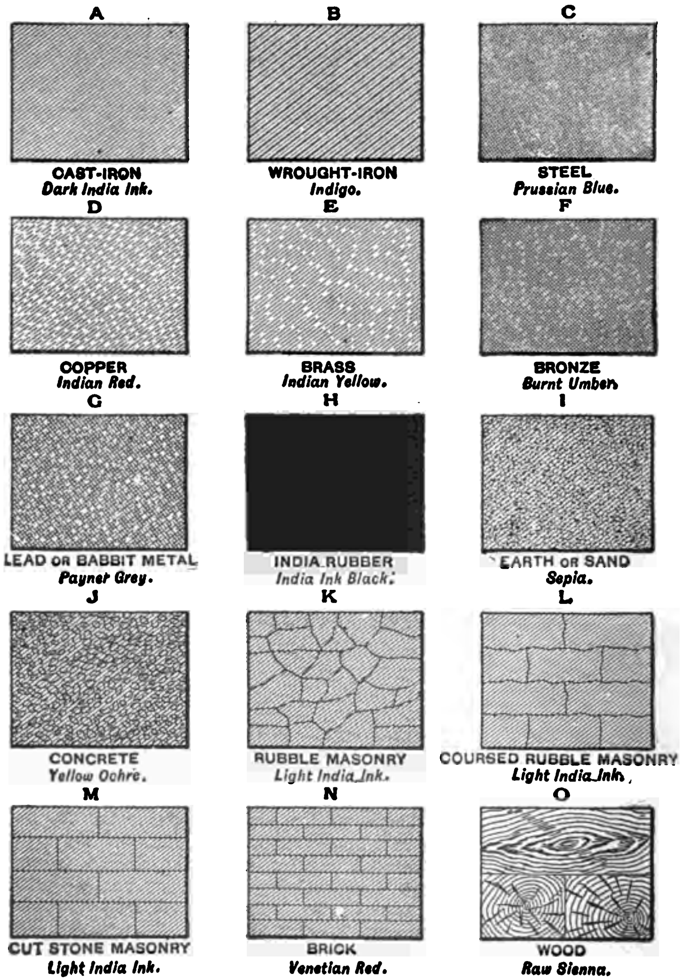
The following information concerning this handy copying process is furnished by H. E. Smith, chemist and engineer of tests of the Lake Shore & Michigan Southern Railway, and appears originally in the *American Engineer and Railroad Journal:*

Clear hide glue, 1 lb.
Water, 1½ pts.
Glycerin, 2½ pts.

The glue should be of a good quality, and the kind that comes in transparent, light-brown sheets, as the white or brown opaque glue does not give as good results. Break the glue into small pieces and soak it in water over night in a covered vessel. Then melt it in a water bath, and add the glycerin, which should previously be heated to the same temperature as the melted glue. Stir only as much as is necessary to mix the glue and the glycerin, as too much stirring introduces air bubbles, which are difficult to remove. Pour the hot mixture through a cheesecloth bag into the pans. When the pans are filled and the jelly is still quite fluid, sweep off air bubbles or impurities from the surface with the edge of a card. Let the pans stand forty-eight hours before using. This formula calls for much less water than usually required by other formulas, since it is preferred to secure the requisite

SYMBOLICAL SHADING AND COLORS.

For Cross Sections of Different Materials.



softness by means of the glycerin, which does not evaporate and allow the pads to dry out and harden, as does the water.

In writing the original copy, always use hard, glazed paper, and write with hectograph ink. In making the negative, moisten the surface of the pad with a cold, wet sponge, wiping off the excess of moisture. Dry off with a newspaper, and let it stand for two minutes. Place the original face down on the pad for from one to three minutes, rubbing down to a perfect contact, and then carefully remove. In printing, apply a clean sheet of any kind of paper, so that it touches the hectograph at all points, rubbing as little as possible. Never use hot water for removing the negative; as soon as the copies are all made, wash off with a sponge and cold water and dry off well with a newspaper. Never let the pad stand with ink on it after the copies are made, and always keep it closed when not in use.

When coloring drawings to be reproduced by clay block or hektograph never wash over lines. Where solid colors are to be shown put them on first. Draw the lines over them if it is found impossible to so wash the colors that they can be stopped at the lines.

On such drawings different colors will represent different materials, and this is to be indicated on a corner of each drawing.

The colors used will be according to the judgment of the man using them and his ability to keep in stock the required pigments and inks. Usually buff will represent wood in plan and light red represents wood in section. Gray, cast iron; light blue, steel; purple, wrought iron; yellow, brass; orange, copper; black, lead; carmine or crimson lake, masonry. In addition to the color for masonry letters must be used and perhaps some conventional signs as well to indicate whether it is of brick, stone or concrete, and whether the concrete is plain or reinforced. Earth will generally be represented by a brown and stone by a darker buff than is used for wood in plan.

For maps different things are represented by the colors above mentioned, which are for construction and structural drawings. On maps electric light and power lines will be represented by red; sewers by orange; water pipes, etc., by blue; gas lines by green; paving by light yellow; sidewalks by the lightest shade of gray.

For profiles and sections of excavations use light brown for ordinary earth; orange for tough clay; light red for hardpan; yellow for sand; light gray for loose rock; light blue for solid rock.

It is usually convenient for reference to use different colored cards in the card index. A system the writer has found good is to

use blue cards for waterworks records; green for gas; light red for electrical work; orange for sewers; gray for sidewalks; yellow for pavements; white for surveys; buff for miscellaneous records. The man adopting such a system can extend it to any desired minuteness and paste a scale of colors above the index box.

Before leaving this subject the writer wishes to make a few remarks about drawings in general. The inexperienced man—and the boy fresh from school—are disappointing when trying to express themselves on paper. They are trained to copy what they term "standards" and rely so much on minutiæ of detail that their drawings are confusing.

The experienced draughtsman never, or seldom, copies. He remembers details that have been called to his attention and incorporates them in his drawings. He never draws from other drawings or models, but uses instead the rudest kind of free hand sketches, often without dimensions being marked on them. That is, the ready and experienced man sees before his eyes how the drawing will look when completed. He is as ready in depicting what he wants as the well-read man is in choosing words to express himself. He does not cumber his drawings with too many conventional signs, but uses as few lines as will express his meaning. Another marked difference between the drawings of the experienced man and the inexperienced man is that the former is not afraid to use plenty of notes on his sheets. The latter seems to be afraid that if all his ideas are not drawn that his work will not be understood.

Remember that all the drawings sent from the office of an engineer in charge of public work will go into the hands of men not skilled in reading drawings. Plain line drawings with little shading or with few attempts at finish (other than extreme neatness and accuracy), with plenty of lettered notes where they will make the drawings clear, will help much toward having work executed right.

DESIGNATING WORK.

The following letters and systems of numbering will help in keeping track of work. Reserve letters as follows:

A for sheets 9x12 inches and smaller.
B " " 12x18 inches and larger than 9x12 inches.

C for sheets 18x24 inches and larger than 12x18 inches.
D " " 24x36 " " " " 18x24 "
E " " 30 inches wide and too long to go with "D" sheets.
F " " 36 inches wide and long enough to roll.
G for width of 42 inches; H for width of 48 inches; I for width of 54 inches; J for width of 60 inches.

O will be reserved for office books; T for field books; P for paving plats and record books; S for sewerage plats and record books; W for waterworks plats and record books; X for electrical plats and record books; Y for gas plats and record books. As everything will be numbered consecutively the prefixing of the proper letter to the number indicates at once where it may be found.

In designating tracings of original maps and plats copied from the records, the writer has a system of numbering in which the first two numbers indicate the year, the next two the month and the last two the day of the month on which the map or plat was filed for record. Thus "C 030207" stands for the 7th of February, 1903, and the size of the sheet is 18x24 inches. "C 981127" stands for the 27th of November, 1898, and the sheet is 18x24 inches.

It is only with such plats the regular numbering is departed from. For all other work each piece of work is given a number as soon as received at the office. This number belongs to that piece of work and no other. The plats, maps and drawings are numbered consecutively, regardless of the job number, which is placed beneath the drawing number on the drawing sheet, thus: $\frac{\text{C947}}{1392}$

When work is abandoned the discarded plats are given another consecutive set of numbers in red ink. The former number has a heavy red ink line drawn through it and the new "Discarded drawing" number is written above in red ink. This entry is also made in the "Job book."

In the preceding chapter the manner in which the "Job book" is used is sufficiently described. The card index system of the writer hardly requires any further explanation, especially when taken in connection with the system of using colored cards, described above.

The writer believes that a city engineer should have a Job Book on the loose leaf system. Certain work is never finished in

a city and as additions and changes are made the index should be capable of indefinite expansion. In the Job Book a simple subtraction of the red ink "Discarded Drawing" number from the serial drawing number indicates the number of "live" drawings in the files. It is for such reason the writer numbers all plats consecutively, no matter what size.

While the letter "A" indicates sheets on file that are not over 9x12 inches in size the sheets that are the size of specification pages should be marked "sA" and be filed in separate drawers until required to be attached to specifications.

Instead of the hektograph or clay process for the small sheets, "positive" tracings can be used and each one colored. So far as the writer is aware there is no perfect paper on the market that will print a dark line on a light, or white, background directly from a tracing. The best process so far is to make a print from a tracing on thin paper that turns brown instead of blue. The lines are in white. This when dried is used as a negative with ordinary blueprint paper and the print obtained has blue lines on a white ground. It involves the making of a tracing and also of a thin negative. The hektograph or clay process requires only the making of one good drawing and the printing of it in an easy way.

SURVEYS AND RESURVEYS.

The newly elected or appointed engineer coming into an office with no records should first make a plat 18x24 inches in size containing all the Government subdivision lines for three miles each way from the center of the town. This map is an index and no dimensions, bearings, etc., are to be marked on it. Simply mark and number the sections, township and range. This plat should be hung on the wall.

Make tracings on cloth or tough tracing paper of all the plats on record in the County Recorder's office covering that district. Each plat to be on a separate sheet. Paste these tracings to heavy detail paper sheets 18x24 inches in size with a one-inch border on three sides and a two-inch border on the left end.

In the upper right hand corner place the number (as already described) indicating the date of filing for record. The plats will be on many different scales and the tracings are supposed to be true copies of the plats. Make books of these sheets and file them serially by date. When one is made draw an outline to scale on

the index plat hanging on the wall and place in this outline the number the sheet bears. On the outside of the cover of the book containing the plats place the numbers "From No. —— to No. ——."

When time permits forty-acre books, section books, etc., should be prepared as described by Mr. Gabelman in the preceding chapter. Mr. Gabelman and the writer are so close to each other in their methods of keeping track of such matters that his method will serve the man who wants to start right and keep it up.

It will be noticed that the writer simply uses a slightly different method from Mr. Gabelman in taking care of the original copies from the records. He afterward reduces them all to one scale in books and if ties are uncertain or are missing, goes out in the field and makes them. Then when subdivisions are platted in between they will fit.

The books are not bound until twenty-five or thirty sheets are put in each. Sometimes they are never permanently bound. Changes are made and the sheets are taken out and altered. The making of such records is good pastime for rainy and dull days and keeps men from growing lazy.

No time should be lost in making plats to connect the recorded plats on one common scale. When it is started the man new at the work will be astonished to see how hard it is to make things fit. If the work is delayed until a survey is to be made it may take several days' work in the office to prepare for three hours' field work.

The foregoing relates almost entirely to lot and street line surveys. It should be the business of the town or city engineer to keep such records and not leave it to several men in private practice, each with a personality that will be surely injected into the work done by his office. There should be one central public place of records and the records in private offices should be merely copies.

For the protection of the public no building permits should be issued until a lot has been surveyed and the street and alley line defined and marked. The plat should be filed in the office of the town or city engineer to be recorded by him and when he records it and properly endorses it as recorded the building permit may be issued. This determines responsibility if mistakes are made in surveys.

A still better method in the writer's opinion is to require that

before any buildings can be erected the city engineer, or some of his assistants, shall define the front and rear lines of the lot and all lines that may affect the public interests. The lines between private property are no concern of the municipality.

The latter method is going to affect the business of engineers in private practice, for if a property owner is obliged to get a certificate for the correctness of the front and rear lines from the city engineer he will naturally employ him to make the whole survey and not pay two fees.

The way to get around this would be to have Licensed City Surveyors. Every man wishing to make surveys that will be accepted by the city in lieu of surveys made by the City Engineer shall be obliged to pass an examination in three sections: 1. His knowledge of surveying in general and city surveying in particular. 2. His knowledge of legal decisions affecting resurveys in cities. 3. His knowledge of conditions in that particular city and his possession of complete records, at least as complete as then filed in the office of the City Engineer. His license to hold for one year and to be renewed free of cost upon giving satisfactory evidence that his records are as full on that date as those in the office of the City Engineer and that he has filed notes and plats of all surveys made by him within the city limits during the year past within five days after each survey had been made. He should be under $5,000 bonds to protect the city in case he makes a mistake and the city has to go into court to compel owners of lots he has staked out to vacate public property.

PROPERTY RECORDS.

For information of a permanent nature relating to property lines and field notes the best plats are on a scale of 100 feet to an inch. These plats should show only lines, angles and elevations (the latter in red ink figures) finally determined by resurveys, and should be in such detail that any competent surveyor can retrace the lines. It is best to plat them on sheets 24x36 inches in size and when a sheet is full have it adopted by the Council as the official map of that district. Such plats will sometimes take many years in the making, for information will be added to them until they are complete. When adopted by the Council they should have a certificate to that effect placed thereon by the City Clerk, under seal, and be filed for record.

Such plats will not follow Government lines so far as their boundaries are concerned. The writer prepared some by first making a map of the city and all its additions and suburbs on a scale of 400 feet to an inch, and this was divided by lines into many spaces, each space representing one sheet. The spaces were regularly numbered and lettered and the sheets filed in proper order. Sheet 17 was near the center of the city and was the first one adopted as official. Sheet 1 was not completed for nine years, as it was in the suburbs.

The elevations marked on the sheets were the official grade elevations. The ground elevations were put on in contours.

Monuments should be placed where necessary, but that will be taken up in a following chapter.

Another set of plats is required and these plats are best when about 18x24 inches in size. The scale is not to be uniform, as the plats are for the study of particularly troublesome points. On some of his plats the writer has used a scale of ten feet to an inch, while on others he has used fifty feet to an inch. He has made most of his calculations on these sheets also, for the plats themselves often occupy only a small space in one corner.

To index these plats their number should be put at the right places on the 400 foot scale map that serves as an index for the officially adopted plats and be also indexed in the card index.

DEPARTMENT RECORDS.

All work should be so done in the office that when the city increases in size and departments are created the records for each department can be taken from the general records without too much disturbance. To have the different department records on colored cards is a start.

There should be a map, or rather a number of plats on a scale of 200 feet to an inch for sewer work, and some on the same scale for street work. When the waterworks come into possession of the city similar plats should be made for the water department and a set made for the lighting department when the city owns the light plant. These plats are usually about 24x36 inches.

The establishment of a separate department then means the taking of the plats and cards from the office of the City Engineer to the department head office. If the departments are still under the charge of the City Engineer as chief, then all numbering, etc.,

should originate in his office and the high numbers in all departments kept there to avoid duplication.

The 200 foot scale maps for sewers should show the size and depth of every sewer in the district. The blocks are to be simply in outline and have no dimensions marked on them. The map lines should be in black ink and the sewers in red ink. Circles represent manholes. Circles with a dot in the center represent catch basins. Squares represent inlets without catch basins. Red circles filled with blue represent flush tanks.

A dotted line leading from the sewer to the clear space inside a block leads to a lettered description telling the date of the contract, number of contract and amount of work done on that contract.

The street maps showing street improvements and paving matters should be on the same scale and similarly treated. Adopt a color for each kind of pavement and wash in the area on the map when the work is done. A dotted line leading into the block ends where a concise description of the work is given. If street car tracks are in they should be shown and also the area the street car company is to keep in repair.

Wooden curbs are shown in brown lines; stone in red; concrete in blue; wooden sidewalks in light brown; cinder in light gray; concrete in light blue; brick in light red.

The water department maps will show the water pipes in much the same manner as the sewer maps show the sewers.

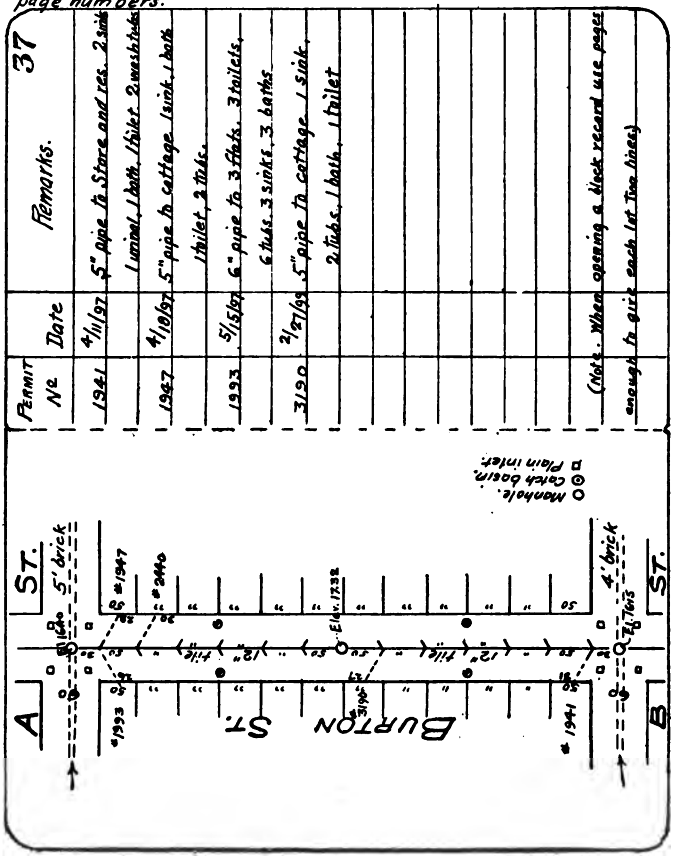
The lighting department maps will be made on the same plan as the sewer and water department maps.

While this seems like a great deal of work it is not too much for a man and his assistants to do and is a wonderful convenience. When departments are formed the city is not required to go to extraordinary expense to have the records copied for each department.

STREET OPENINGS.

Records of street openings are kept in three ways. One way is to use a card index and show it on that. A second way is to make a plat of each block in a book having pages about five by eight inches ruled in squares. The blocks can be plotted to scale as each permit is issued, or, rather, as the first permit in each block is issued. One book should be used for each department

The object of these books is to show at a glance the conditions in each block as a whole. Detailed information about each connection is given on cards—one card to each. The same system is applied to water, gas, etc. Cards give book and page numbers.

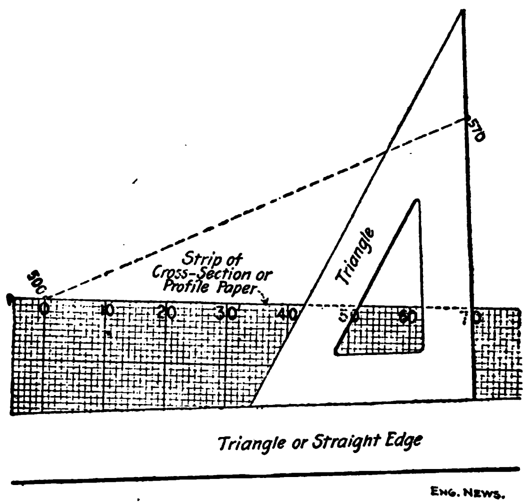


STREET OPENING RECORD.

(or future department.) The third way is a combination of book with cards.

The plat shows the two sides of the street from one corner to another, including one crossing at the end of the block. Plat on the street thus put down, the sewer, or the water or gas pipe, etc., and then plat in the right place the connection when it is made. Mark the date, etc., and number of the index card and all information that will help. In this connection remember the plat is to be on the left hand page and the other page can be used for notes.

The card index should be by streets and contain all particulars that will be necessary in determining the location of the connections made. These cards to be in the colors selected before for the departments in question.



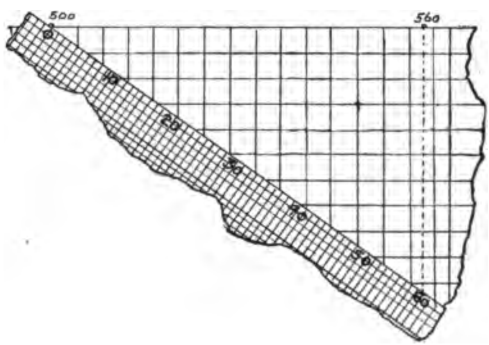
The cards are filed alphabetically by streets. File them regularly in the direction of the house numbers. The permit book has numbered stubs so that is all that is needed for number reference to permit.

CONTOUR MAP.

The City Engineer should have a contour map on a scale of 400 feet to an inch. The lines in black should show only the

outlines of the blocks and need not be marked with dimensions. Upon this map should be platted all elevations determined at any time, and when enough are platted the contours can be drawn in, selecting any interval the judgment of the engineer dictates.

For interpolating contours the writer has used for years a method described by him in *Engineering News,* May 10, 1900, a cut of which he is enabled to reproduce by the courtesy of the editors. The elevations are written at the proper points and a dotted line is drawn connecting two points on which the elevations have been determined, and which are platted in their relative positions. A piece of ruled paper, marked as shown, is laid at any angle and one end is at one of the points. That is, the figure on the slip of paper is the same as the elevation of that point. A triangle is then laid on the plat so that the edge passes through the other point and the number on the slip that corresponds to that elevation. The triangle is then moved along another triangle, or a straight edge, and at each contour interval decided upon a dot is marked on the line connecting the two points.



In the issue of June 21, 1900, of the same paper, Mr. H. F. Bascom, C. E., described a method, original with himself, which is superior. He lays a strip of ruled paper along a line connecting the two points. This piece of paper has no figures marked on it. He then lays on top of it another strip having graduations, such as above described. This last strip is placed at an angle so that one graduation touches the elevation on one point so marked and

the other end of the strip intersects a line that intersects the marked elevation of the second point. By following lines to the edge he plots his contour points. This is shown in the illustration.

For a ready method of covering a large area preparatory to a study for sewerage and drainage nothing can compare with the stadia method and a contour map.

The old time tedious calculations for reducing stadia readings have been superseded by diagrams and slide rules. Messrs. W. and L. E. Gurley, Troy, N. Y., sell for 75 cents the Cox Stadia Computer, which the writer has used for a number of years with great satisfaction.

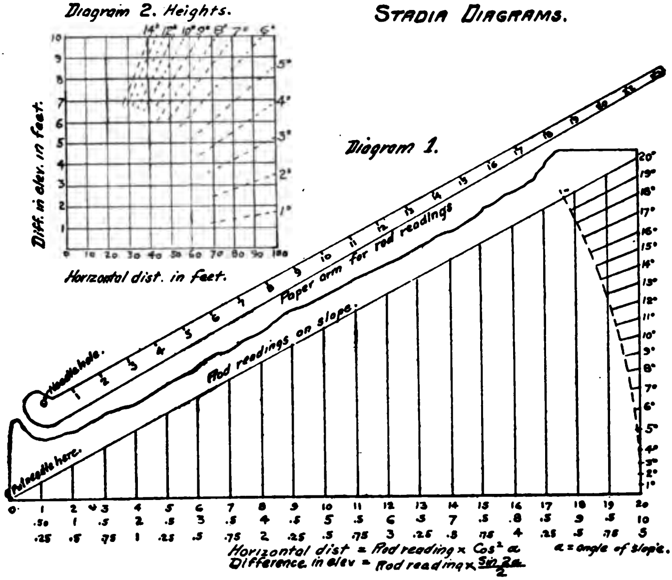
The Cox Stadia Slide Rule, 10 inches long, costs $4.50, and a 20-inch rule costs $12.50. The Webb (cylindrical) Stadia Slide Rule is about 10 inches long and is so made that it is equal to a straight slide rule four feet long. The price is $5.00. All instrument dealers sell them.

Stadia diagrams can be readily made, but being large, are confined to office use. The computers above mentioned can be carried to the field. The formula for horizontal distances is: Rod reading x Cos^2. a. Use a large sheet of bristol board and along the lower edge draw a line twenty inches long divided into twenty parts. Divide each part into ten. From the left hand end describe an arc with a radius of twenty inches. Number the divisions on the bottom line, commencing with 0 at the left end and ending with 200 at the right end where the circle begins. By the above formula compute the horizontal distance for a rod reading of 200 feet and for every degree up to about twenty. Plot each distance as found on the bottom line and erect a perpendicular to intersect the arc. From the vertex at the left draw an inclined line through the intersection on the arc and produced to intersect a perpendicular erected from the 200 point on the bottom line.

Such a diagram is shown in the accompanying illustration. Calculations can be made for quarter degrees or for every five minutes if desired and also plotted. Through each inch point on the bottom line erect a perpendicular in black ink. At each tenth point erect a perpendicular in fine red ink.

Lines can also be placed on such a diagram to give elevations, but it is tedious plotting them. The writer uses another diagram for elevations. He first obtains the horizontal distances on such a diagram as above described and for elevations makes a diagram on

cross section paper, ruled in squares. The vertical scale is ten times the horizontal scale on Diagram 2. A pin is inserted in the lower left hand corner and a thread attached to it. On the right hand side angles are marked by taking the tangents from a table of tangents. On the left hand side the elevations are marked. Stretching the thread to cover the angle, the horizontal distance is read on the bottom and followed up a vertical line to an intersection with the thread when a glance to the left will give the difference in elevation.



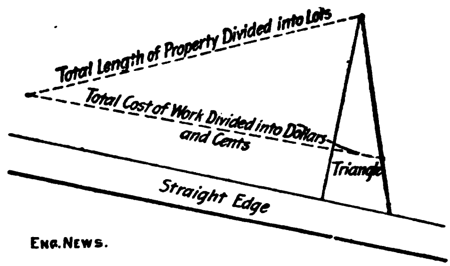
In obtaining the horizontal distance from Diagram 1, an arm is made one inch wide and about twenty-four inches long. It is graduated along the upper edge like the bottom line of the diagram and under the 0 point is some reinforcement of heavy paper. A fine needle is put through the 0 point on the arm and on the lower line of the diagram. An assistant calls off the angle and the arm is swung to it. The rod reading is called off and is read on the arm. At the point of intersection with a vertical line the eye

drops to the bottom and there the horizontal distance is at once read off.

Such diagrams have a value that ordinary slide rules and computers do not have. The latter are graduated for a fixed relation of the stadia wire interval to distance. It occasionally happens that stadia wires (fixed wires are the worst offenders) will change interval for some reason or other and instead of the ratio being 1:100 it may be 1:98 or 1:103 or some other ratio equally a nuisance to compute. The change in the interval is sometimes caused by the wax softening. This has happened to the writer several times until now he uses adjustable wires. The interval he tests three times each day on measured lines.

When the ratio changes (with fixed wires) it is only necessary to ascertain the new ratio on a measured line and make an arm to use for it instead of the arm that is regularly graduated for the constant ratio of 1:100.

While on the subject of diagrams attention may be called to



the following figure illustrating a rapid method of assessing cost of work on frontage. This the writer has used often for estimates. The cut is from one that appeared in *Engineering News* illustrating an article on the subject by the writer some years ago.

MUNICIPAL SUBSURFACE CONSTRUCTION MAPS.

Under the above title *The Engineering Record* of April 1, 1905, printed an article by Hubert S. Wynkoop, Electrical Engineer, Bureau of Electricity and Gas, Brooklyn, N. Y., with a plat which has been redrawn for this book in order that the details can be seen clearly. A reduction of the original cut would not have been clear.

He explains the map and gives the reasons why it is necessary to have such records. To engineers and contractors operating in towns and cities fairly well supplied with modern conveniences his reasons are good. To men in small places where the work of tearing up streets may be said to have hardly commenced his article would hardly appeal.

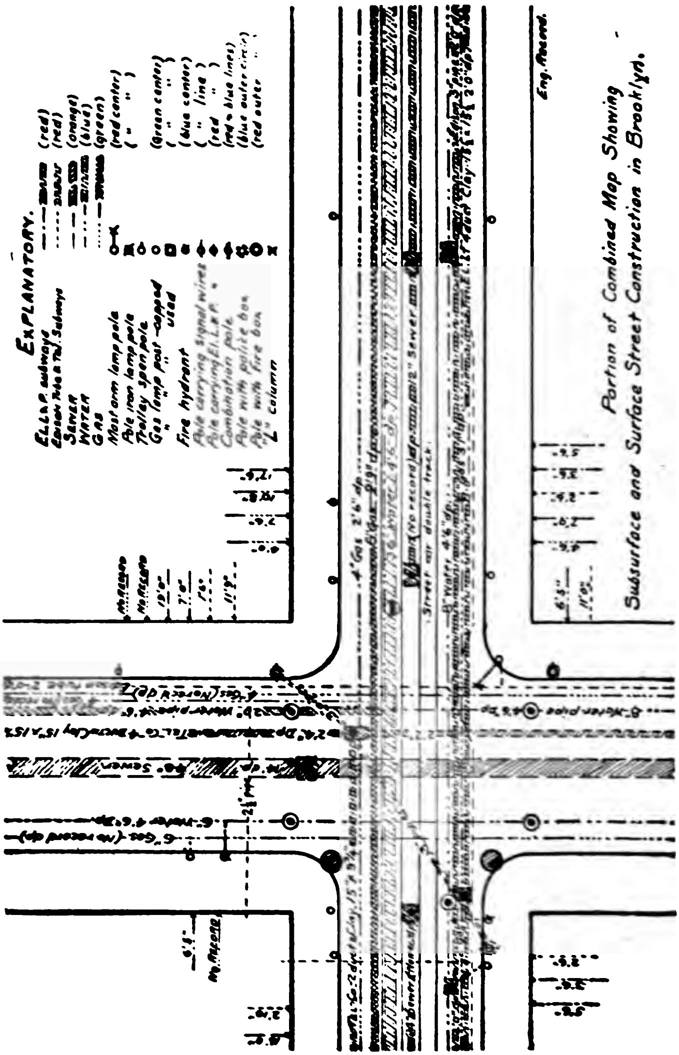
Sometime in the history of every town the underground pipes, conduits, wires, drains, etc., become a great annoyance and expense. All for lack of a little care and forethought, or perhaps because of downright stinginess on the part of the first officials, who would not pay the cost of having maps made.

The writer in his contracting experience has many times been obliged to lower water pipes, etc., when putting in sewers, because no one knew when the plans were drawn, how deep the obstructions were in the ground. The writer, when making surveys for waterworks and sewer systems, bores down where pipes, etc., are known to be and puts the information on the profile. If the location of the obstruction is not known, then of course no borings can be made to ascertain the depth, and digging trenches across at every corner is too expensive.

The lack of definite knowledge often interrupts public work for long periods when obstructions are encountered and blocks the street until enough information can be obtained to permit the work to proceed. Or until the company owning the obstructions can be settled with. In many cities troubled with sewers backing up the trouble is found to be with pipes run through the sewers by workmen employed by gas or water companies, and even the city.

Mr. Wynkoop says: "Let no town deem itself too small to undertake such a work (i. e., having complete records prepared). Who can predict what degree of future greatness lies in store for the little town? As to these maps, I advocate then, for cities, large beginnings; for towns and villages, small beginnings; but for each city, town or village at least a beginning."

Today a contractor desiring to open a Philadelphia roadway makes application for a permit, stating the character and extent of the proposed work and suggesting an approximate location. When the permit reaches him it is accompanied by a sketch drawn to scale and indicating the locations of existing construction as well as the definite location assigned for the proposed work. The



Portion of Combined Map Showing Subsurface and Surface Street Construction in Brooklyn.

permit is accompanied by a bill for the information, usually charged for at from two to five cents a running foot.

The above suggests a method by which the City Council can get the money back for such work. Make such a charge that ultimately the work will be paid for by the men who open the streets. The way to do this would be to establish a fund and all fees received will go into it. Also the bills of the City Engineer and his assistants for the surveys, plats and inspections will be paid from that fund. Of course it would mean an original appropriation.

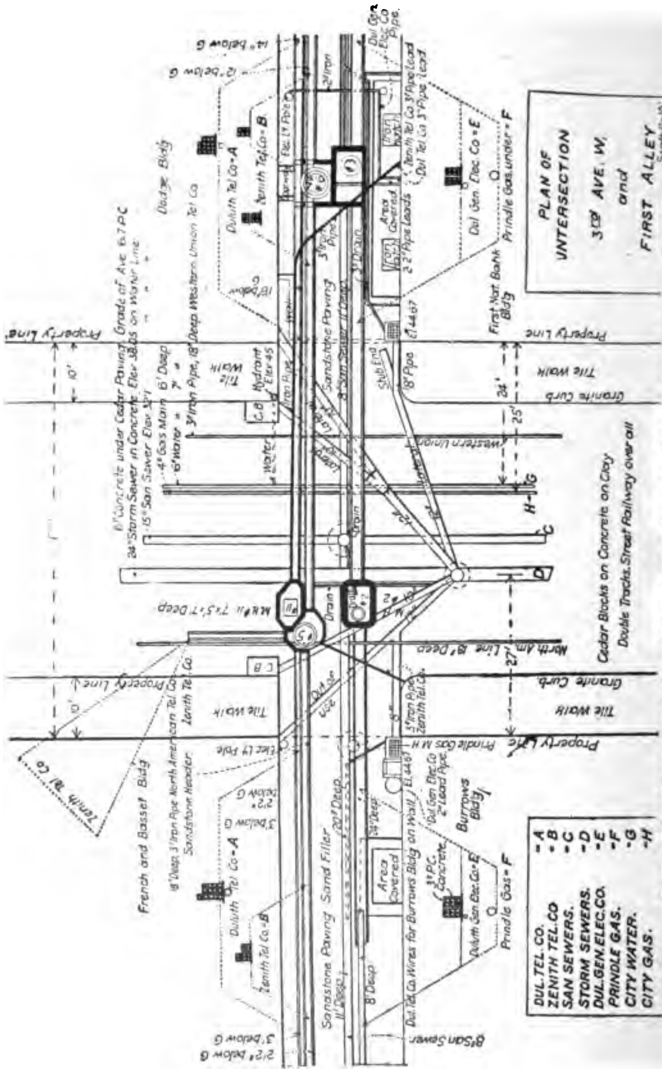
The Brooklyn maps, under the charge of Mr. Wynkoop's department, are 19x27 inches, on linen backed paper. The scale is 20 feet to the inch. Dimensions and depths are marked directly upon the constructions, but distances from curb are indicated by appropriately colored and numbered offsets placed back of the house line.

It has been found of great advantage to have all constructions placed on one map instead of having separate maps for water, sewers, electric lines, etc. The map then shows at a glance all discrepancies, missing links and connections.

The color scheme is as follows: Curb lines, house lines, tracks and all surface or supersurface constructions are in black; all subsurface constructions are in colors, as indicated by the parenthetical notes attached to the key on the cut. Sidewalks are washed in with pale yellow. Practically all lines are solid, the color affording sufficient distinction.

Several other readers of *The Engineering Record* discussed underground maps, and on July 22, 1905, a map was printed, drawn by J. C. Bush of Duluth, Minn. A careful inspection of this map shows a wealth of information.

The writer knows towns where the officials of the privately owned waterworks and electric light and gas plants are at the mercy of the superintendent. He has fought the making of plats on the score of expense and at first the officials weakly agreed. Afterward they could not get them made, for the superintendent alone knew where the pipes and gates were and refused to tell. A number of very old and inefficient men hold their jobs today because of such lack of method. In one city the writer was employed to make a survey after the superintendent died suddenly of heart trouble. The work was taken by contract and was pushed as expeditiously as possible. The cost to the company was $1,486.75



Map of Underground Conditions at a Duluth Street Intersection.

and they kicked about paying it. The contract price was $1,400, and the $86.75 was on account of a helper putting a steel line rod through a wrought iron pipe. The cost to the writer was $1,600 and a few cents. He will never again undertake such a piece of work by contract. There was too much loss of time. Old employes had to be hunted up and their statements substantiated by digging for pipes and valves. Sometimes trenches had to be dug clear across streets. Many holes were dug where men said certain valves, etc., were located, only to prove disappointing.

TRACK RECORD MAPS.

This drawing is a reproduction of an illustration from the *Street Railway Journal* August 15, 1905, showing the manner in which the Birmingham Railway, Light & Power Company (Ala.) keeps a record of tracks, etc. The drawings are made on sheets 46x17½ inches, the record proper being within border lines 42x15½ inches. The character of the pavement is indicated by lines, macadam being shown by diagonal lines run from lower left to upper right, brick pavement by vertical broken lines, granite blocks by double sectional diagonal lines from lower left to upper right and upper left to lower right.

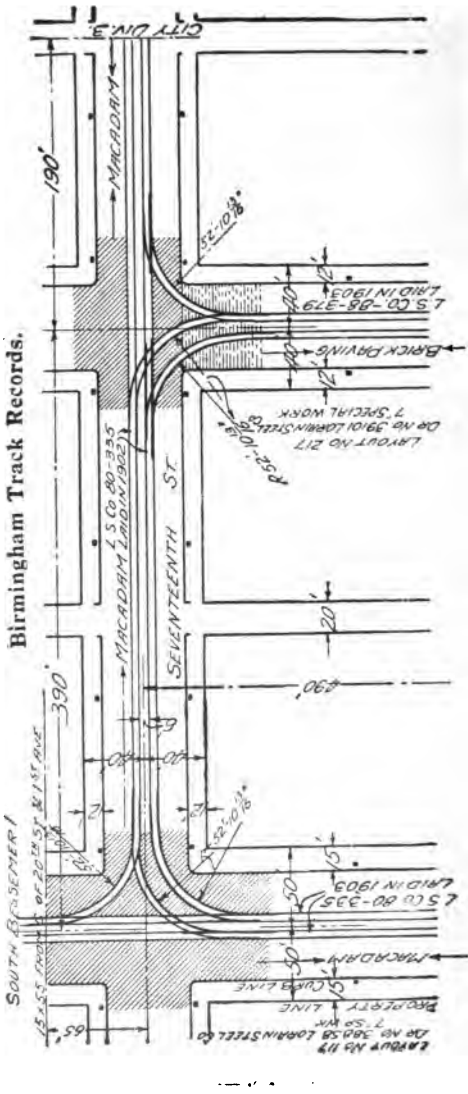
Profiles are made upon the same size sheets to a scale of 50 feet horizontally and 10 feet to the inch vertically. The man writing the article does not state the scale of the maps, but the writer presumes, as a matter of convenience, the maps will be to the same horizontal scale as the profiles. The drawings and profiles are intended to be complete and show class of construction, materials, pavements, character of special work, location of poles, and in fact everything that may directly and indirectly affect the work of the company.

POSTAL CARD RECORDS.

Too many engineers have the habit of putting off office work until winter sets in. Much valuable data is collected that could be of use to all the assistants, but is denied them, with the exception of the man who has done the work, until a wet season gives an opportunity of recording the data in proper form.

The writer has used with good results postal cards addressed to the City Engineer or to the man in the office whose business it

Birmingham Track Records.



SECTION OF DRAWING SHOWING TRACKS IN PLAN WITH DATA.

is to keep track of such matters. The cards are kept in a pocket in the back of the field book or under a rubber band on the page opposite the record page.

When a bench is established, or a line point or monument fixed, copy the description from the field book immediately on to the postal card. Drop this in the nearest mail box and it will turn up in the office in due course. The proper man in the office will at once make an entry where such entries should be made. The next time an assistant goes to the field he will find fresh and reliable data at hand. This will also stop the pernicious habit of taking field books from the files out to the field and probably losing them. No field book should ever leave the office after it is full and has been indexed. This system, with illustrations of forms, was explained by the writer in *Engineering News* February 15, 1906.

MONUMENT AND BENCH MARK RECORDS.

In the preceding chapter the writer has given a system for keeping track of monuments and bench marks.

On the card index record cards a full description of the point is given and sometimes on the back of the card a sketch (not to scale) is drawn illustrating the description.

No matter how many departments there may be the office of the City Engineer is the place where all such information belongs and duplicates of his records in the departments will be all that is necessary if the heads of the departments wish to keep such records themselves. That is, there should be some central office where all information in the way of bench marks, monuments, survey, points, etc., can be found.

LEVELS AND PROFILES.

Dunham's Plat and Profile Book is a fairly useful book for the purpose of keeping profiles in shape to take to the field.

The writer, however, has found it a good idea to have leather covers made 9x4½ inches in size and to cut profile paper into sheets that will fit these covers. Holes are punched in the end and brass pins used to hold the sheets in place. Such a book can hold about twenty sheets.

When a contract is awarded for sewers, water pipes or underground conduits the profile is platted on one of these sheets for

one or more blocks, together with all the information necessary. On the back is platted the block. Sometimes the engineer first uses the sheets and places on them all the information he acquires from setting the grade stakes, and notes changes (if any). The draughtsman in the office inks the information in, leaving the old matter stand, but crossing through and making corrections in red ink where changes are found necessary. Then the inspector keeps it on the job and marks the different kinds of material as they are encountered. When the job is completed the sheet is turned into the draughtsman, who finishes it for the purpose of record, in accordance with the scale of colors already mentioned. The sheets are then filed by streets in a box made especially for them, or in little books of fifty sheets each and card indexed.

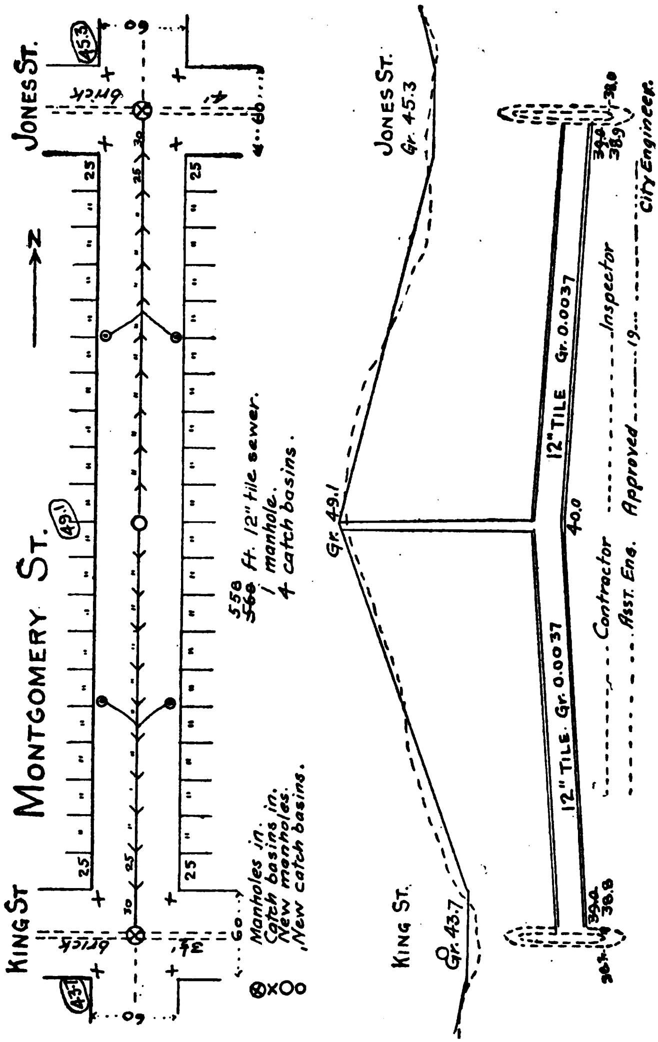
The putting down of the information as to character of material encountered in excavating is of great value as time goes on. After a while it enables an engineer to give very accurate information and make close estimates when trenching and excavating work are proposed.

The cut here presented shows how the plat is made and how the profile looks. The marks crossed out indicate corrections made in red ink. Sometimes the procedure is as follows: One copy is made for the office, one for the engineer, one for the inspector, one for the contractor and one to be attached to the office copy of the contract. Four copies altogether.

The copy given to the engineer is marked by him as to elevations and distances when the work is completed and mailed in to the office, where the information is taken from it by the draughtsman and marked on the office copy. The inspector then uses his own copy instead of one already marked by the engineer and puts on it all the information he secures, and when the job is completed mails it to the office, where the draughtsman takes the information from it and corrects the office copy. After both plats have been received fully corrected and showing the work as it was actually done, the draughtsman plats the information on the 200 feet scale maps in the sewer department.

The plats for the waterworks, gas works, street paving, etc., are similarly treated.

The writer has drawn each plat very often and he has also used another method very successfully. He had a rubber stamp made in the form of a roller which printed a cross section plate


MONTGOMERY ST.
KING ST
JONES ST.
N
558 ft. 12" tile sewer.
1 manhole.
4 catch basins.
Manholes in.
Catch basins in.
New manholes.
New catch basins.
Gr. 49.1
Gr. 45.3
Gr. 43.7
12" TILE Gr. 0.0037
12" TILE Gr. 0.0037
Contractor
Inspector
Asst. Eng.
Approved
City Engineer.

in transfer ink. As the roller was complete the plate could, of course, be any desired length. The width was 4½ inches. On the plate thus made with the roller the profile was marked, together with the line of sewer, etc., in transfer inks.

The completed sheet was then printed by the clay or hektograph process. The plat was also drawn in colors with transfer inks on another piece of paper and printed on the back of the profile sheet. The rubber roller was marked in one-quarter inch squares, thus making the form known as Plate A. The longitudinal scale was 100 feet to an inch and the vertical scale four feet to an inch.

In some cities there are used sheets ruled in one-quarter inch squares on which the plat is put at the top and the profile of surface and sewer below. The sheets are prepared a long time ahead and when needed the work is traced with transfer inks on cloth and printed. The cross section lines do not show on the printed sheet.

The writer's method of procedure is as follows: When levels are run profiles are made of each street in continuous sheets as is customary and cross elevations are checked. This information is then placed on the 400 foot map and contours drawn. When a study is made for grades the proposed grade is worked up on both map and profile. It is then marked in lead pencil on the profile and the grade ordinance is prepared. After the ordinance is passed the adopted grade is put on the profile in red ink, together with the date and number of the grade ordinance.

On the contour map the contours of the original ground surface are in black for rock, brown for ordinary soil and in yellow for sand. When a grade is established the official elevations are placed in red inside of circles at the correct points. Then the new contours, as they represent the surface when brought to grade, are put on in red ink.

An immediate study is commenced for sewerage and drainage, the results being placed in lead pencil on both profile and contour map. When the time arrives for action and the work of putting in the sewers or drains is to be performed the lines are inked in red on the profile, together with sizes and elevations and grades. The work always remains in lead pencil on the contour map, for it is a working map.

FORMS OF PROCEDURE.

It is difficult in such a book as this to give blank forms to cover all cases, as proceedings are governed by statutes and the statutes vary in all the States.

Generally, however, the work of the engineer in connection with public improvements may be arranged as follows: Work originates in one of two ways, by petition from the interested property owners or by some member of the Council. The engineer is then called upon for a report and recommendation. If these are favorable an estimate of cost is made. It is well to make the estimate of cost as soon as the report is made, for it may be called for immediately after the report is read and ordered filed.

The estimate should include a definite description of the boundaries of the proposed improvement and of the limits to the district to be assessed for the cost.

When it is finally decided to proceed with the work then get from the heads of each department all information that will enable proper plans and specifications to be made. Instruct the street car companies, electric light and gas companies, water companies, underground conduit owners, and all who have easements and rights in the street that the work is to be done and direct them as to what they have to do before work can commence. When the contract is awarded send proper notice to all.

Have regular bidding sheets on which all information for comparison of bids will be placed. When the contract is awarded make out a card for a record containing the number of ordinance under which the work is done, the date of same, date of bidding and date of award, name of contractor, amount of contract, class of work. On this card to be lines to contain the names of the inspector or inspectors and of the engineer or engineers in charge of the work.

For the convenience of the office force and to expedite business the writer has the inspectors supplied with two sets of books. One book is used for Monday, Wednesday and Friday. The other book is used for Tuesday, Thursday and Saturday. The inspector is obliged to report at the City Hall every evening and turn in the book for that day, getting the book for the next day. If the distance is too great, arrangements have to be made for an exchange of books.

The books are ruled in squares and have no other ruling. On the right hand page a lead pencil sketch is made of the work. As a rule it is platted on a scale of 100 feet to the inch longitudinally and ten feet to the inch across and vertically. It does not take long to instruct a man in preparing his own sketches from the profile and plan given him. If he can not do the work get one who can. On the left hand page he puts explanatory matter.

The clerk in the office, or the engineer himself in a very small place, makes the proper notes each day from the inspectors' reports, and when the work is completed there can be no extraordinary rush and hurly hurly to give finals.

When employing assistants see that each one completes his work on time and leaves nothing to be done later in the season. If field work takes only a few hours each day see that the necessary office work is done the same day, and then let the men go for the balance of the day if they wish, instead of having them put in a few hours in the field and loaf the rest of the day, only to be upset and hurried later on when the necessary office work must be done by a certain time.

When a certificate of the completion of any piece of work is given by an assistant it should be countersigned by the chief. He should not attach his signature until he has examined all the records and found them complete as concerning that job. Until his signature is attached the contractor can get no money. It is not right for a man to attach his signature to any document that draws money from the public treasury until he knows that all the records are clear.

It is an excellent idea when much work is going on in several parts of the city to have all the inspectors supplied with postal cards properly ruled on the back to mail each night to the City Engineer, giving an idea of the progress of the work and any matters of importance they notice in connection therewith.

HOUSE NUMBERING.

A house numbering map, or set of maps, is required if the city has free mail delivery.

One method of numbering houses is to assign 100 numbers to each block. This is convenient when the city is laid out on a rectangular plan and follows Government subdivision lines.

It is not an advantage when the blocks are irregular in size and is a nuisance when a new street is opened or a street is closed. The writer has been called upon to devise house numbering systems for a number of places, and the last time solved the matter in the following manner:

The city was platted on a scale of 100 feet to an inch on sheets of cross section paper ruled with ten squares to the inch. A point of origin of numbers was selected one mile away from one corner of the city limits in the direction it is believed the town will have no growth. Proceeding from that point each ten feet represents an odd and even number. The odd numbers are on the right hand side proceeding from that point and the even numbers are on the left. This gives 1056 numbers to a mile, counting the total, or 528 on each side of a street in a distance of one mile.

On the plat the lot lines are marked and when a resident wants his house number he measures the distance his door is from a lot line and a glance at the map and a measurement tells him the house number.

From the selected point the numbers proceed in two directions, and the writer used due east and due north in the particular instance referred to. When curved roads or roads running at an angle are met with the average direction of the road determines which set of numbers to select. If the distance is east or west of northeast or northwest or southeast or southwest then the easterly running numbers are selected. The length on the lot line to each number, of course, is greater than ten feet. If the average direction is nearer north or south then the northerly running set of numbers is selected.

In the residence district where large yards are the rule there are several numbers to each lot that may never be used. As the business part of town builds up and as flat buildings increase it will be seen that every entrance can have a number. As no attention is paid to blocks streets can be opened or closed without disarranging the system of house numbering.

Where a town is located at the junction of two rivers or a lake and river, etc, the point of origin can be taken in the water some distance away from the town. Where the town is located in the middle of a prairie or a spot where it can grow indefinitely in any direction the point of origin should be taken at the intersection of the two principal streets and the numbering can proceed

either way. Knowing that each number represents five feet, distances can be closely approximated when two numbers are given. So the city hall, the court house or the intersection of the two principal streets become good starting points.

To avoid confusion in names and the letters N., E., W., S., so often a nuisance, names might be given the streets as follows: In the northwest quarter (or any other) let all the streets running in one direction be numbered and be called streets. The streets crossing them at right angles to be numbered and called avenues. In the southwest quarter have a similar arrangement but use letters instead of numbers. In the northeast corner use the names of trees and flowers in a similar manner. In the northwest use the names of local celebrities. For wide avenues and irregular streets use names of states, etc. It would mean, for example, that Elm street would stop at Massachusetts avenue (or boulevard) and its continuation on the other side would be Fifth avenue. This is better than East Elm and West Elm. In many cities numbers proceed east and west from a selected street or a canal or a river and the streets keep their names. After a man has lost an evening traveling to visit a friend on 2689 Madison avenue he finds to his disgust that the friend lives on W. Madison, but in writing forgot to put down the distinguishing letter. Not knowing there were two directions to travel the stranger had taken a car on Madison avenue which seemed to be traveling in the direction that would take him to the house he wished to visit.

The duplication of names and alleys should be avoided. Many cities have a number of streets with the same name. In the above system stick to the streets on all that go in one direction and to avenues on all that go in the other direction. A duplication of names will not be confusing then. Streets at an angle with the general plan will be called boulevards if over seventy feet wide and avenues for any other width.

If there happen to be any streets in circles the rectangular system of house numbering must be departed from for those streets. Select a starting point and go around the circle, giving one odd and one even number each ten feet.

RECORDS FOR VERY SMALL PLACES.

For very small places the writer advises the plat book contain-

ing the tracings of original plats on record and the copies of them on a scale of 100 feet to an inch.

For record books get books having pages about eight by fourteen inches ruled in quarter inch squares. Enter everything in these books each day. Make plats or copies of written notes, plats of surveys, copies of reports, finished profiles, cross sections for estimates and for grading, etc. Omit nothing. When one book is completely filled get another.

The pages should be numbered and the contents card indexed. A number of places use such records and they are amply sufficient for general purposes until the town grows large. If the card index is complete there will never be any necessity for making copies of these records when departments are established or when the office pays enough to enable an engineer to install a more comprehensive system.

A separate small book alphabetically indexed can be used to keep a record of bench marks and a similar one for records of monuments and survey points. If the city owns the waterworks or the lighting plant similar books can be used to locate hydrants, valves, gates, transformers, etc. The records should be in the large books and these small books contain only copies to take to the field.

CONTRACT DRAWINGS.

For structures try and keep drawings to a size not exceeding 18x24 inches. Such drawings should be general drawings only. Try and make all details on sheets of legal size to bind in with the specifications.

For street and sewer work and for laying water pipes, gas pipes and conduits there should be a general plan on as large a scale as will permit it to be platted on a sheet that will bind in with the specifications. This plan should not show the street lines, but merely the pipe lines with the names of the streets placed along them.

Mark on each line the sizes and approximate lengths of the pipes or conduits. Also the material. Such a plan gives a contractor an excellent idea of layout. In the same lot put a drawing of the cross section of the street, if a paving job, showing thickness of each layer of paving, foundation, etc.

In the same lot of drawings show all details and all special

sketches necessary or useful in laying out the work. In the front of all have an index alphabetically arranged and at the bottom of each sheet have the page number prominently displayed so it may be readily found when wanted after referring to the index.

In addition have a plan and profile as before described on a sheet about 4½x9 inches of each block separately or of two blocks if they will go on the sheet.

Avoid blanket sized sheets and sheets crowded with details stuck in in almost any imaginable way. Do not plat a number of drawings and profiles on one large sheet of transparent profile paper and make blueprints from it. It may be convenient for the engineer who has studied over it when working out the matter, but it is annoying to every one else. It argues that the man who prepared it might be lazy or stingy, or both.

A small sized general plan giving dimensions and approximate quantities on each block is a wonderful help to a contractor in distributing his material and in prosecuting his work. The writer can speak feelingly on this point, for he was a contractor's engineer in many places where he wanted to do serious bodily injury to the engineer who drew the plans and made the drawings.

A little thought for others is a big asset in this world. To bind all the profile sheets in a cloth covered pasteboard back, easily opened and referred to on the job on a windy day, takes very little time. Any intelligent man can do it and it is one of the things that brings its own reward.

Specifications can be duplicated at the lowest cost by blue printing. Use a very thin typewriter paper with a rough surface, or at least a surface that is not shiny and smooth like the paper known as onion skin. Write on it with a black copy ribbon placing behind it a piece of pencil carbon paper. Ink carbon makes too light an impression. The face of the carbon paper will be against the paper so that when the work is done the black ink from the typewriter ribbon will be on the face of the paper and the black impression from the carbon will be on the back. These sheets can be blue printed as readily as any drawing. It is well to make the signed originals in this manner and corrected copies can be made whenever wanted at a cost of from one to two cents per sheet. Black pencil carbon is not always readily purchased for the majority of stationers keep blue carbon paper. This is a good method also for reports. By using douhle faced carbon for the first sheet a duplicate copy may be made at the time the original is printed on the back. By using thin ink carbon for other sheets a number of carbon copies may be made in the usual manner, this method having the advantage that copies may be produced at any time in the future by simply preserving the original which is written in black and has the extra impression on the back. The author uses this method altogether now.

CHAPTER XIII.

FIELD WORK.

STANDARD TAPES.

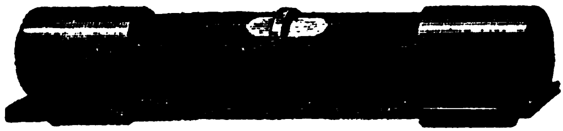
Sometimes, but very seldom, it happens that a city laid out years ago was carefully surveyed and monumented. But there is a difference in the measurements with measuring done at a later date and the difference is constant and in one direction. It is not an error but if good judgment is not used there will be errors introduced by reason of this difference. All the lines should be gone over carefully between monuments with a standard tape and the difference ascertained. Then the city should have several tapes made which will be correct only when applied to work between the monuments but of course will differ from a standard tape by the amount of the constant difference found.

An ordinance should be passed forbidding the erection of a building or fence in the city until the applicant for the permit has had the lot measured and no one should be permitted to do the measuring but a licensed city surveyor or an employe of the city engineer's office, and it should be done with one of the tapes made for that purpose.

MEASUREMENTS.

In measuring lines too great care can not be exercised. Steel tapes graduated to hundredths of a foot are the best to use and it would be well to send them to Washington, D. C., to be tested by the government, before using them. It takes only a short time to accustom men to using a spring balance on the end of a tape. A common spring balance can be purchased in nearly any hardware store for thirty-five cents which serves excellently. It is about nine inches long and an inch in diameter. The writer uses also a tape level (on which he obtained a patent in 1892) in nearly all his work. It is attached to the tape by clamp springs so placed on the

bottom that a simple "twist of the wrist" attaches the level to the tape. Some engineers prefer a level on each end but one is sufficient. The level is placed about one foot away from the end and the tape pulled to the proper tension and then raised or lowered until the bubble indicates that the ends are at the same height.



After this it is not necessary to pay any more attention to the bubble for a man can keep the level thus ascertained, easily enough. A hundred foot tape requires about a sixteen pound pull. The bubble should be in the middle of the tube for short distances of about twenty-five feet or less and move toward the hand for greater distances (for allowable sag) until on a tape one hundred feet long, with sixteen pound pull it is almost at the end of the open space.

Mr. J. C. Sala, instrument maker, 429 Montgomery street, San Francisco, Cal., recently purchased from the writer the patent for the above tape level and is the sole manufacturer.

For measuring on streets with good stiff grades and where the tape has to be used in short lengths the best method is to use a fifty foot tape and measure on the slope, putting twenty penny nails at the end of each measurement, i. e., at each fifty feet. The tape should be hauled taut each time. Then run levels over the road and read the rod carefully at each nail. The distance can be reduced to the horizontal by using tables of squares and there will be no danger of the work not afterward checking out. This is a good method for running out a base line for initial surveys, and for triangulation for stadia work. When so used, instead of nails, place stakes at the end of each measurement. The stakes should be about one inch square with chamfered tops and a tack in the center on top.

A further advantage possessed by this method is that data is obtained for profiles. The stations will be somewhat irregular but after the profile is platted that will make no difference.

MONUMENTS.

Monuments should be either of granite or concrete four inches square on top and several feet long, set at the intersection of the center lines. The top should be a few inches below the street surface and it is well to have the top serve as a bench mark for levels as well. The bottom should be larger than the top. A good temporary monument is made of a two inch iron pipe two feet long, driven into the ground, filled with wood and having its center determined by a nail driven in the top. On out of the way roads and lanes where no improvements have been made a good monument is made by taking a post hole digger and putting down a hole two or three feet deep. In the middle of this hole drive a stick one inch square, exactly centered. Fill the space around with a lime paste. Such a monument is cheap and lasting. It was first used by George C. Power, city engineer of San Buenaventura, Cal.

When a street is improved the monuments should be carefully referenced and replaced. It is a good plan when a concrete curb or cement sidewalk is built to place in the cement a few nails from which to make further surveys and thus avoid the nuisance of tearing up the street surface, and also because it is generally easier to work along the edge of the curb than in the middle of the street.

While the writer mentions the location of monuments at the intersection of center lines it is not intended to be considered as positive. Circumstances may make it advisable to locate the monument lines on off-sets. A common plan is to set all monuments on streets running in an easterly direction, ten feet south from the center line. On streets running in a southerly direction to have the monument line ten feet east of the center line.

While the exact center line is almost always the clearest line a surveyor can obtain, when no street cars use the street, monuments placed in the center are apt to be disturbed by sewer construction. In fact, it is hard to know just where to place monuments where they will not be disturbed and where the surveyor can always use them conveniently.

The writer has found concrete sidewalks to be good places in which to set monuments and a distance of six feet from the property line a good distance out. When using sidewalk marks or monuments it is necessary to have a tripod made of well seasoned wood or strong metal tubing to hang points from. This tripod should be

seven feet long and have gimbal rings in the top. Fastened to the gimbal rings should be a straight iron rod three-quarters of an inch in diameter and two feet long. It should be hung in the gimbals about the middle and at the lower end should be a ring to which to attach a plumb line. Fastened to the plumb line should be a plumb bob weighing at least two pounds and a pasteboard tube six inches in diameter and two or three feet long should be held by an assistant to protect the plumb bob from being swayed by passers by or by the wind.

When the plumb bob is exactly centered over the point the rod (which is painted red and white) is of course erect. A shifting center can not be well arranged on such a tripod, which must be centered by shifting the legs.

Another method often used for sighting points, not requiring the attention of an assistant, is to have a pole to stick into the ground, with a plumb bob suspended from an extension end. When the pole is planted the extension end is moved until the plumb bob is directly over the point. Then a prop is placed under the pole. Sighting is done to the plumb line. There are many such ideas in use original with the men using them. Such a device requires to be steady in the joints, and very rigid in every way. While better than a man, who may not always pay attention to his work, it is not safe to leave them without a man near by to see that they remain fixed and are not interfered with.

MARKING OF SURVEY POINTS.

In macadamized streets the best material for points, to be used again, are twenty penny wire nails, the heads driven about one inch below the surface and referenced by measurement to sidewalks, curbs, fences or buildings. In unpaved streets wooden stakes one or two inches square with bevelled heads driven one inch below the surface will last a long time. This is of course in places where there are no monuments or on parts of streets where it is a long distance to a monument.

The recovery of points is embarassing sometimes. Marks on buildings and fences are liable to disappear and the engineer can hardly be too particular. He should make several ties, choosing preferably a brick or stone building when he has a choice. For a point in an earth street where surveys are seldom made and refer-

ence points are liable to disappear quickly a good method is to make a ring with a fifty foot, or twenty-five foot tape and on this ring drive half a dozen stakes with their tops flush with the surface. Tacks should mark the exact distance from the point to be preserved. Tie in all these points as well as the center, and when it is required afterward and the direct ties have disappeared, it may be found when any two of the tie stakes are found and a measurement from each, with the radius of the circle, will intersect in the proper place.

The markings of buildings should be systematic. A common way to mark a line measurement is to drive three nails or tacks in a vertical line. It is understood that the middle tack is the one to measure from. For elevation three or four nails in a horizontal line with one projecting slightly for the level rod to rest upon is a common method. The diagrams in the record books describing these points should be carefully drawn. Transmitted from one city engineer to another and carefully kept up such records are of value. Less will be heard then of the disagreement of surveyors, than is now heard in every small place.

THE RESURVEY OF LOTS.

These surveys are generally made for building purposes. A diagram is given the party ordering the survey and is not always drawn to scale, but shows all adjacent, or encroaching improvements, together with the amount of the encroachment or the distance away of the parts on which the marks have been placed. Where a tack has been placed to mark a line it is indicated by the word "tack" and the distance from that point to the point defining the lot line, is marked in red ink, the diagram being in black. Elevations above or below certain points indicated on the diagram are shown in blue.

In the resurvey of a lot there are four cases to be considered:

First—There may be a monument at each end of the block.

In the first case measure carefully from one monument to the other and distribute the difference, if any is found, proportionately between the monuments, unless it interferes with buildings already erected of permanent material. In such case, if there is a surplus and the client can be given his land without taking from others,

make an adjustment and note it in the records. The diagram will show the client he is safe and the records will keep future city engineers from getting astray. It is well to verify the monuments occasionally from others, as they are often disturbed.

Second—There may be no monuments, but there may be buildings already erected, supposedly by survey.

When buildings or fences are in it is common to measure from the nearest, assuming it to be correct. It is a loose practice, but if there is nothing to go by it is well to verify from each end of the block the correctness of the location of the fence or building taken as a starting point. When monuments are out or have been disturbed it is customary, and wisest, to treat each block by itself, regardless of others. If the measurement discloses a surplus distribute it proportionately between the points or buildings disclosing it and if there is a deficiency it is generally safest to throw it into the street if not great in amount. The sidewalk can stand it.

Third—There may neither monuments nor buildings but the curbs may have been set.

When curbs have been set it is customary to set the transit on the curb line and sight along it as far as possible to get a clear sight. As curbs are seldom out more than an inch or so and the sight obtained may be several hundred feet while the depth of the lot seldom exceeds one hundred feet, an error in the side line from an angle turned from the curb will be too small to consider. Most of the lots surveyed in even large cities, lacking regulations over this important part of the surveyor's business, are surveyed in this manner. So long as there is no grumbling and every man gets his land, while the city has enough street width there should be no objection, provided careful records are kept.

The curb along the front of the lot gives the line. The curbs at each end of the block are the points from which the distance is measured. The width of the sidewalk having been found at each side line of the block that distance is set off from the curb and stakes driven. The distance between these stakes is then measured and compared with the official distance. Any surplus discovered is distributed as described above. If the distance falls short each stake is moved toward the curb until the distance agrees with the recorded distance, leaving the shortage in the sidewalk. If the former surveyors have measured from each end of the block and the

buildings occupy so much space that the client can not get his land, show him the facts and let the owners fight it out.

The end stakes having been adjusted the line is then measured down the block until a point is reached in front of the lot, where a clear sight can be had to the end. Set in a tack point for the transit and turn the angle. Measure across the width of the sidewalk and set in a stake for the front line. Continue the measurement with care to the depth of the lot (which it is presumed has been ascertained by measuring on the end lines of the block as described for the front). Set on each stake and turn the angle to set the corner stakes; or mark the adjacent buildings or fences, which is preferable to driving stakes liable to be disturbed during building operations. If not easy to measure along the lot lines it is customary to measure along the curb line as an offset. Then the marks for the side lines in front can be placed on the curb.

With a wooden curb set three nails in the shape of an "L," the nail at the angle and on the upright portion being on the line and the other nail being on the inside of the lot. These three points will be shown on the diagram and the distance marked to the front line of the lot. If the curb is stone or concrete chisel an "L" on top.

If the block to be surveyed is between blocks (not necessarily adjacent thereto) having curbs or buildings, it is easy to carry the curb or building lines across these blocks, on all four sides. The corner stakes thus found can be adjusted to conform to the dimensions and angles given on the official plats and the survey proceeded with as above described. It is well after completing the survey to drive at the block corners four by four posts with tops flush with the ground and having a nail set in to indicate the exact corner point. Future surveyors will then be likely to perpetuate these points by basing their surveys of lots in that block upon them.

Fourth—There may be neither monuments, buildings, fences or curb lines within reasonable distance.

If the lot to be surveyed is in a block not near one having curbs or buildings, and where there are no monuments, the surveyor meets with problems he must settle for himself, according to circumstances. He must proceed with all possible care with the best information obtainable and should be chary about discrediting the work of previous surveys and re-surveys until he has actual

documentary evidence in his possession which will convince the most ignorant man that his work is right, even if it does not agree with some previous work.

It has been remarked that "surveying is an art and not an exact science." This is especially true in cities and towns where the data are incomplete and yet the land so valuable that every man wants to get possession of every fraction of an inch he is entitled to.

The judgment of the surveyor is frequently taxed and he must reason from an assumed standpoint with correctness. It is strange to say that correct results can be reached by using hypothetically correct starting points, but the problem is simply to give a man his land so he can occupy it. If he gets a piece of land the size he paid for and gets it without interfering with the rights of others and with no danger of future interference who can say the surveyor was wrong in scientifically (?) "fudging" his work, so far as starting points are concerned?

At the close of Chapter XIV is given a list of the requirements of the modern architect as to information to be placed on survey plats for building purposes.

BENCH MARKS.

Permanent bench marks should consist of concrete posts four or five inches square on top and about eighteen inches square on the bottom. They should have the top a foot below the grade and the bottom should go below frost line. As a usual thing they will be about four feet long. The best location is just inside the curb line near street intersections. There should be a box a foot square put around the top to protect it and this box should have a cover having a lock to which only the engineer and some of his assistants should possess keys.

Such bench marks are expensive and one on the corner of each mile generally suffices. Between them the engineer can establish elevations on parts of buildings, hydrants, valve gates, etc. Elevations on hydrants and such objects should be checked every time they are used, for they are not stable. For permanent work only the standard bench marks should be used. The others are for use during construction only.

Benches on stone or concrete curbs are often more satisfactory than on hydrants. It is only a few minutes' work to read and

record elevations, so the engineer should always have several elevations close together where they can be reached at one set up. Check on all before using one.

For lines of levels the limit of error in feet should be kept down to 0.04 times the square root of the distance in miles. All levels should be run in circuits and close on the starting bench, or on some bench previously checked from it.

In running the first levels for benches in a town it is a good idea to run a line around the outer boundary and close on the starting bench. Then adjust the elevations on each point read and run cross lines each way. The engineer can not have too many points of known elevation. He generally suffers from not having enough.

SETTING STAKES FOR WORK.

The writer has little use for stakes when there are fences, buildings or curbs to mark. It is too easy to render a stake valueless and make it dangerous to a man's reputation. If cuts and fills on street work are considerable there will, of course, be several sets of stakes set on the work. The final marks only, need be set on good points.

If the grading is only a foot or two deep the best way to set marks is to measure along the edge of the sidewalks, or along the front of buildings, and put in nails at regular intervals and number them. Measure over and set a nail at each end of the block on the curb line. Set the transit on one curb nail at one end of the block, and sight to the other. A leveling rod, reading to hundredths of a foot, can be held on each nail driven in the fences and buildings and horizontally across the curb line. The engineer reads the rod and at once obtains the distance out from that nail to the curb, which distance he proceeds to record in his book and has his rodman mark in lead pencil, or black crayon on the building or fence, above the nail.

After getting these distances out he proceeds to take the elevations of each nail and marks in blue above the nail the height it is above the curb or below the nail the depth it is below. A diagram is given to the contractor showing all this information. He needs no more stakes, but proceeds to set his curbs first, then excavates for the gutters and roadway, sighting across from curb to curb with properly graduated stakes, to get intermediate heights and for

crowning the roadway. The nails are then in position for checking at any time. In addition to these permanent marks it is sometimes well to set stakes for subgrade, the top of the stake being at the proper elevation.

When given to the contractor, the distances out from the nail to the curb line are marked in blue and the elevations above or below are marked in red underneath like a fraction. A plus sign indicates that the curb top is to be higher than the nail. A minus sign indicates that the curb top will be below the nail.

There are several ways of doing everything and in nothing is it so marked as in staking out work, especially for sewer construction.

The writer has been required to set two stakes to grade, one on each side of a trench and at such a height above the bottom that the stakes were either below the surface or just flush with it. The stakes were four inches square and a trench was dug from one to the other and a two-inch plank spiked to them. The top of this plank was then a definite distance above the bottom and level from one stake to the other. The earth was tamped in round the planks, which were set some time before construction. They were used by stretching a string or fine wire from one to the other along the center line of the trench, from which the inspector measured down to the pipe.

He has been required to give stakes on the bank and when the contractor had excavated to within about six inches of the bottom to set grade stakes in the bottom at the elevation of the outside of the pipe on the bottom.

He has been required, and it is the custom now in many cities, to give rough stakes and when the contractor had excavated nearly to the bottom to give stakes to a "gage line." With pipe sewers this "gage" line is six inches above the top of the inside of the pipe. With brick sewers it is at the center line of the sewer, half the diameter above the bottom.

He has been required to set stakes on the bank to a grade line and when the street has a fairly uniform slope this is accomplished by "plunging." A stake is set at each end of the trench at a certain definite height above the sewer grade line. The level or transit is set over this stake and the exact height measured with a steel tape to the axis of the telescope. A rod with a target fixed at that height is held on the other stake and the line of sight

directed to it and the instrument clamped. The rod is then carried along the line and held on stakes at different points, which are driven until the line of sight intersects the center of the target. The work is checked by reading again on the first stake. Sometimes a permanent mark is placed on a building or post so the instrument man will have a constant check.

If the slope of the street does not permit of "plunging" then the stakes are set to grade in the ordinary way. Some will project considerably above the surface and some will be below it. When either thing happens a change of one foot is made in elevation. The contractor is then told, or rather the inspector is told, how far to measure to the grade line.

Sometimes the inspector measures carefully and sometimes he does not. The writer does not approve of any method involving the setting of stakes to grade where they are likely to be disturbed. He does not approve of any method of measurement except from a string or wire stretched along the center line of the trench.

His preferred method—for circumstances sometimes make us do a little less than we consider best—is to set the line with a transit and put in stakes twenty-five feet apart at some regular distance from the side of the proposed trench. This distance depends upon the character of the ground and varies from six inches to six feet. When trench machines are used it is generally six feet from the center line of the trench, to avoid being disturbed by the wheels.

The stakes are all driven flush with the surface or an inch or two below. Then elevations are taken on the stakes. A profile is made, or the grade elevations are computed and placed in the level book and the difference taken. The differences are given to the inspector. He drives a two by four into the ground as close as he can without disturbing the stake and on the opposite side of the trench drives another. By means of rule and carpenter's level he marks a line on the nearest two by four by actual measurement from the grade stake according to the figures given him by the engineer. He puts a scantling across to the other stake and clamps the scantling to both. The carpenter's level is used to make the scantling level across and at the right height. A cord is then stretched along the center line from one scantling to another and measurements taken from it to the sewer. "Like

swallowing, it is easier done than described," as Shunk said when telling how to set slope stakes.

For measuring down, use a rod one inch square having on the lower end a projection making an exact right angle. The projection is generally a piece of round iron rod and the depth is measured from a cut on the pole to the top of the iron. The end of the projection is inserted into the top of the pipe. To insure verticality the writer generally has a level tube inserted into the rod near the top or has some arrangement made for plumbing it.

MARKING JUNCTIONS IN SEWERS.

The first junction in a sewer is generally placed at a distance of twelve and one-half feet from the property line at the lower end of the block. From this point on the junctions are placed at intervals of from twenty-five to fifty feet, depending upon the contract, one junction pointing to one side and one to the other. The distances are recorded by the inspector by a continuous measurement from a manhole.

Inspectors do not always measure accurately and records are sometimes lost. Junctions can not be found readily and plumbers make connections with sewers without always taking proper care.

The writer for many years has marked the junctions with stakes set in the trenches. There was a discussion in Engineering News on the subject two or three years ago which developed the fact that it was a common custom but also one that did not meet with favor with a certain class of engineers who are disposed to think measurements are infallible. To mark junctions, use pieces of wood one inch or so square or get edgings from mills near by. The writer in one place used willow branches. Set them at the junction and get them vertical as nearly as possible. The top will terminate a couple or three inches below the surface. When hunting for a junction it makes no difference how poorly the measurement was for the record. The plumber does not have to dig more than three inches before commencing his search for the marker. He need not dig deeper until he does find it. When found it is only necessary to go straight down, following the stake to the bottom. When he makes the connection he should replace the marker for use in locating the other junction at that point.

The inside of the bottom of sewers is known as "bottom,"

"invert," "flow line" and "water line." There may be other designations but the above are all the writer has encountered. His own practice is to call it the invert, but he runs across many who understand only the word "bottom."

GENERAL WORK.

For buildings and other structures the writer generally sets his stakes and makes his marks so that all measurements are to the exact lines. The contractor can make his own offsets. Most contractors prefer to do so. The writer does not always set stakes at corners, however. Many times it is most convenient, and in fact best, to set the stakes on the lines of the buildings two or three feet from a corner so that strings stretched across will intersect at the corner. Like lot surveying such work must be left to the judgment of the man doing it. Circumstances always alter cases.

SIDEWALK GRADES.

The writer has several times been called upon to make a survey of a small place and give grades for the construction of sidewalks. It was in places that had no resident engineer or surveyor and the people did not want to call one in every time a sidewalk was to be constructed. The method he adopted was as follows:

First, a good point was selected as an initial bench mark and a height assigned to it. From this point careful levels were run on all the streets, measurements first being made down each side of each street and the "plus" marked at the side of each door jamb along the line. If the buildings were back from the street line more than five feet a stake was placed on which the plus was marked just opposite the door.

Then levels were run and the elevations taken on the door ledge at the side of the frame against the house, where no wear could occur. Where stakes were set to mark a "plus" they were driven flush when the rodman had called them off and the rod was held on them as well as on the door step.

Elevations were also taken on the ground on each side of the street and in the middle. On the profiles all the door steps were platted and the elevations marked. When the grades were fixed the elevation of the sidewalk grade opposite each door was

marked on the profile. A nail with a round brass head was driven at the point the rod was held and a book given containing notes for each street. This book had pages ruled in columns. In the first was the house number if it had one. The second column contained the distance of the door from the nearest corner. The third contained the difference in elevation between the brass headed nail and the elevation of the sidewalk when it would be built. This was given in feet and inches and eighths of an inch. The last column gave the name of the owner and the tenant of the house, with necessary remarks.

The book was filed with the town or village clerk and whenever any carpenter wanted to put down a sidewalk to an official grade he could get correct information from these records. The book also contained full directions for laying out long stretches of sidewalk on grades by means of straight edge and level.

In making surveys for sidewalk and other improvements take the following readings:

Property line.
Curb line.
Gutter.
Center of street.
Farther gutter.
Farther curb line.
Farther property line.

The above readings should be taken about one hundred feet apart when the street is on a slight grade and does not require much work. Where irregular the readings may have to be in fifty foot stations. Sometimes less. At street intersections the readings in the above order should be taken on the diagonal cross lines.

STADIA SURVEYING.

The writer has always made great use of the stadia method of surveying and finds it about as low in cost as anything imaginable. For city engineers it is especially handy on tracts of land having no buildings or fences to mark the street lines and where time is an object. In such cases set the instrument at a point that can be readily tied to the lines on the tract on the office maps and make a stadia survey. The map can be plotted and all the contours placed on it before plotting the street lines. The writer has found

it a help in platting new subdivisions and has often laid out tracts of land with contour roads on such maps. In this connection the following, from an article by the writer in Engineering News, May 11, 1905, is in point:

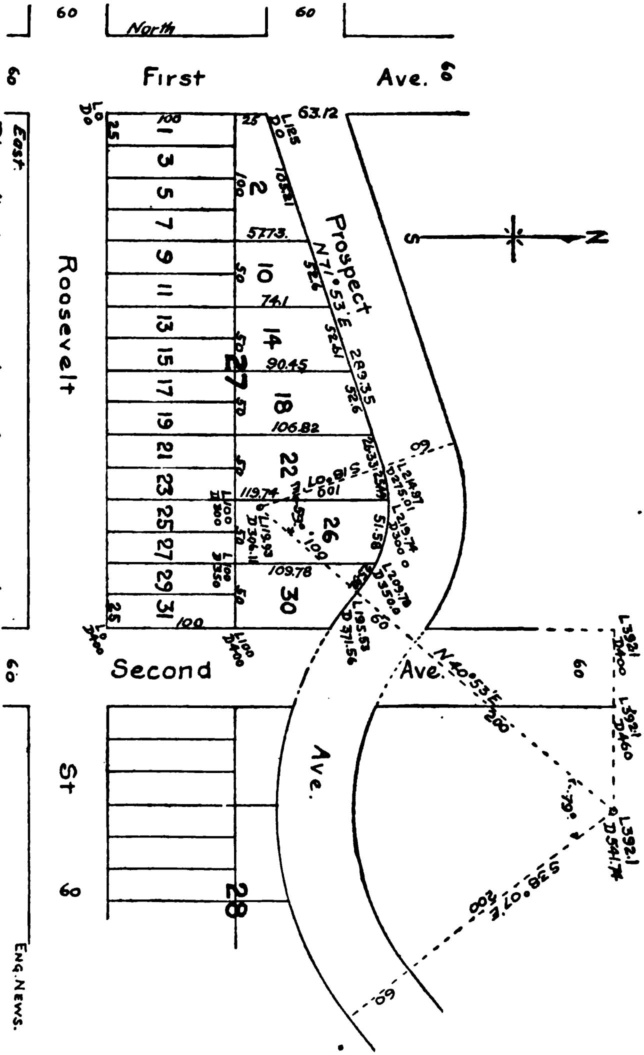
"The blocks (in a certain tract surveyed by him) were 400 feet long and 200 feet wide without alleys; streets 60 feet wide; lots 25x100 feet. All the above dimensions were fixed for the owner by the real estate agent before any surveys were made. The writer had instructions to lay out the ground on this plan with rectangular lots and keep all street grades down to 10 per cent. Whenever the slope of the ground did not permit such a grade, or a lighter one, he could deflect the roads and do it with curves. Along the brow of a steep hill he was to run a curved avenue and what the lots lacked in depth could be made up in width.

A stadia survey was made of the steep hillside and of all parts where the maximum street grade might be exceeded. This was platted on a scale of 100 feet to an inch with 5-foot contours. The boundaries of the tract were laid on the map, and the regular subdivision as planned drawn on it in lead pencil. Fine red ink lines, dividing the map into 100-foot squares were next carefully drawn. They were used for scaling co-ordinates to check the calculations.

The southwest corner of Block 27 was taken as the point of origin, of latitude and departure points, for the curved road commenced in that block. The hill road was stepped off on the contours to the proper grade and curves drawn as shown.

It will be readily seen how the latitude and departure distances were obtained for all the lot corners up to the B. C. on the front of lot 22 in Block 27. The radius being normal to front of the lots 2, 10, 14, 18 and half of 22, it was easy to calculate the latitude and departure for the center of the circle. Likewise it was easy to calculate the point of reverse curve and the E. C. of the following curve. The central angles were measured with a protractor, but, if the calculated distances varied more than 5 feet from the scaled distances, the angle was changed and the distances recalculated. This was a paper location to be transferred exactly to the ground, as a map was to be completed and filed before a stake was set. The owner was anxious to sell quickly.

The problem was to get the lengths, between lots, of the lines



Plan illustrating method of laying out lots on a curved street.

terminated by the sides of the curved roads and also the frontage length, as the lawyer insisted that "Lot 22 in Block 27, etc." was not a sufficient description and all distances had to be written in deeds.

Taking the line between lots 22 and 26, the south end has Lat. 100 and Dep. 300. The center of the curve has Lat. 119.93 and Dep. 306.11. Taking a point due west on the lot line we get Lat. 119.93 and Dep. 300. This gives a right-angled triangle having an altitude of 6.11 feet and a hypotenuse of 100 (the radius of the curve). The base of this triangle is 99.81, which added to 19.93 gives the length of line between the lots as being 119.74 feet; Lat. 219.74; Dep. 300.

The angle at the base is 3° 31′, hence the bearing of the hypotenuse is S. 3° 31′ E. and the difference of angle between radius to B. C. and radius to end of lot is 14° 36′. The length of the circumference of the circle is 628.32 feet.

$$360^\circ : 14^\circ\ 36' :: 628.32 : X$$

therefore the length of the curved portion of the front of lot 22 is 25.49 feet.

Similarly, taking a point on the line between lots 26 and 30, due east of the center of the circle, a point is obtained having Lat. 119.93 and Dep. 350. This gives a right-angled triangle with altitude of 43.89 feet and hypotenuse of 100 feet (radius). The base is 89.85 feet; added to 19.93 feet, gives a total length of 109.78 feet and the corner on the avenue between the lots has Lat. 209.78 and Dep. 350.00.

The angle at the base is 26° 02′, hence the bearing from the center of the curve to the N. E. corner of lot 26 is N 26° 02′ E. The bearing to the other corner we found to be N 3° 31′ W., so the included angle is 29° 33′.

$$360^\circ : 29^\circ\ 33' :: 628.32 : X$$

therefore the length of the curved front of lot 26 is 51.58 feet.

The included angle between radii to corner between lots 26 and 30 and the points of reversed curve is 14° 51′.

$$360^\circ : 14^\circ\ 51' :: 628.32 : X$$

therefore the length of the curved front of lot 30 from the corner to P. R. C. is 25.92 feet.

To check:
Curved front of lot 22 .... 25.49 feet
Curved front of lot 26 .... 51.58 feet
Curved front of lot 30 .... 25.92 feet

Total length curve .... 102.99 feet

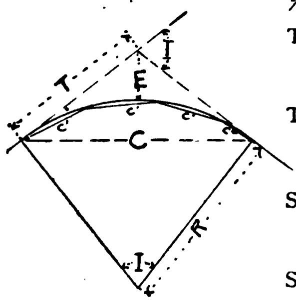
Total included angle is 59°.

360° : 59° : : 628.32 : 102.97 (check).

The lines drawn on the diagram indicate the method of procedure for the next curve.

Care must be taken to check all calculations by measurement on the map.

In recording the map the dimensions of the lots as found are placed on it, and the radii of all curves drawn to an intersection, with the length of radius marked, together with central angle. It would be a great help to future engineers if all Lat. and Dep. measurements were tabulated on the map."



C = long chord.
c = chord.
½D = defl. for c'.

$$T = R \tan \frac{I}{2}$$

$$T = \frac{\frac{c}{2} \tan \frac{I}{2}}{\text{Sin. } D}$$

$$\text{Sin. } D = \frac{\frac{c}{2}}{R}$$

$$\text{Sin. } D = \frac{\frac{c}{2} \tan \frac{I}{2}}{T}$$

$$R = T \cot \frac{I}{2}$$

$$R = \frac{\frac{c}{2}}{\text{Sin. } D}$$

$$E = R \text{ ex. sec } \frac{I}{2}$$

$$\text{Chord defl.} = \frac{c^2}{R}$$

$$\text{No. of } c = \frac{\frac{I}{2}}{D}$$

Tan. defl. = ½ chord defl.

The foregoing tells how the calculations are made for lot lines when curved roads are run in. The writer has never seen the subject taken up in text books.

To stake out the work the front line is run in after the lengths

of the side lines are calculated. Having the Lat. and Dep. of each of the two corners on the street it is an easy matter to calculate the bearing and distance. Thus a crooked traverse line is run on each side of the street and the lot corners set in that way. For filling in, the accompanying formulas are used to get lengths of chords, sub chords, etc., and the lot corners being the B. C. and E. C of the curves bounding the lot a check is had on each. The writer uses chords of from five to ten feet in setting out the curves and the carpenter when building the fence drags a garden hose or large rope around them. He can then set pegs as close together as he wishes. It will be noticed the exact curved length is given. It is done because in future resurveys some men will use a longer chord length than others.

To calculate the length of the angular front of a lot or block the writer generally uses a table of secants. The width of the lot is the base, the front is the hypotenuse. The difference in the bearing between the straight width and the slant front is the angle. Multiply the width by the secant of the angle to get slant front. To get the difference in the lengths of the side lines multiply the tangent of the angle by the width. Given, the slant width of a lot and the angle at the base of the triangle multiply by the sine of the angle to get the difference in the length of the side lines and multiply by the cosine to get the straight width across.

If the engineer has no table of secants he can use the following formula:

$$\text{Secant} = \frac{1}{\text{Cosine}}$$

or he can divide the straight width by the cosine of the angle to get the slant front, the hypotenuse.

The writer has frequently made surveys of tracts of land by the stadia method and laid out in several places base lines with stakes set one hundred feet apart, connecting his instrument stations to these base lines by careful tape measurements. The base lines are generally measured on the slope as described earlier in this chapter.

Very careful study is made of the most difficult parts of the tract and in some cases parts of roads are laid out on the ground at the time the topographical map is made. All the data having been

obtained the contour map is made and the subdivision platted on it, the lots, etc., being calculated as already described. The points on the base lines are connected to the lots and several parties can be set to work staking out the lots when necessary.

Periodic discussions arise in engineering papers over curved roads, as much trouble is experienced in relocating them. All the trouble can be obviated if the man who does the original work is careful to give full notes. He should place on the map the information already mentioned and in addition put on the center line of the road. This is best tabulated on the map outside the plat. He should give full notes for a traverse line consisting of the long chords of each curve and the chords of reverse curves with B. C. and E. C. and P. R. C. plainly designated. At distances closely approximating five hundred feet he should put in some form of monument. He can not err in putting down plenty of information.

The tabulated information will have a column giving each station number and a column for the Lat. and Dep. respectively, of the point. Then the bearing and length of the line. Then three columns headed respectively, B. C., P. R. C. and E. C., and a column giving radius of curve and whether to the right or left. This, of course, for the center line. The Lat. and Dep. being on the lot corners, it is no trouble to calculate the bearing and distance to any lot corner from any point on the center line of the street.

In one place where the writer did considerable work the streets were all irregular and he had the Lat. and Dep. calculated for every corner in the place before he left. Until an engineer tries such a method he can not realize what a convenience it is.

A useful survey was made with the stadia in a town laid out with irregular roads and where the original notes were lost. The maps on record contained no notes and the lots were simply numbered. Encroachments by fences were numerous.

A tracing was made of the maps on file and enlarged to a scale of fifty feet to an inch. Then a stadia survey was made of fence lines and buildings and platted on the same scale. The tracing was found to fit on some individual blocks but did not fit as a whole so the adjustment of the street lines was made block by block. The stadia map was inked in and one block after another of the enlarged tracing was pricked through on it after as careful an adjustment of the lines as was possible. Some of the fences were

undoubtedly correct and others as surely wrong. Latitude and departure squares having been ruled on the stadia map center lines were fixed as closely as possible and a set of notes computed. They were then run out on the ground. At each angle point measurements were made to each side of the street and the points shifted until they were fitted. Then an accurate taped survey was made of these adjusted points and a map made and adopted as official. It took time and patience and when finished was perhaps as nearly correct as such a survey, made after so many years, could be when few original fences were left. Many of the stakes in existence were claimed to have been changed by interested property owners as the man who made the map simply put down the widths of the roads and numbered the lots and blocks. The original map, however, was carefully made to scale.

A transit used for stadia surveying should have a horizontal circle graduated from 0 to 360, preferably to the right (in the direction the hands of a clock move) so that 90 represents East; 180, South; 270, West. Occasionally the O represents South, 90 West, etc., but the principle remains the same. It is convenient if the compass circle is graduated to correspond, for the needle then checks the vernier reading.

Set the instrument on a carefully referenced point and set vernier "A" (the vernier at the eye end of the telescope), at O. Let the needle swing and move the whole instrument until the needle also indicates O. Then clamp. Unclamp the upper plate and direct the telescope to some point as a foresight and begin taking the sights. In the book put down "Set up on Sta. O," and write a description, all on the left hand page. On the right hand page it is advisable to have a series of concentric circles spaced about ten to the inch, the center of the circles representing the station. Graduations to single degrees can be marked on the outer circle. This is very handy for sketches and when such a book is used it is good policy to use one page for each station. Sketching is not necessary but is a wonderful help when there are many fences, buildings, etc., to be noticed. The writer for some years used "positive" blue prints on thin paper for this purpose and carried a bunch to the field with him, pasting one in each page of his field book. Lately, however, a field book for such work has been made and is sold by Engineering News.

The columns on the left hand page are as follows:

Horizontal angle (from zero).

Vertical angle (plus or minus).

Rod reading.

Needle reading about every fifth and sixth shot.

The above are filled in the field and the sketches made. The latter are filled in the office.

Magnetic bearing (calculated).

Total elevation above datum.

Horizontal distance. The manner of calculating distances and elevations has been described in a previous chapter.

In platting, a large paper protractor is used with the center cut out. The writer draws two fine lead pencil lines on the map through the initial point and lays the protractor down so that they intersect the four ninety degree points on the protractor. The upper edge of the protractor is pinned to the board.

A piece of paper is glued to the O point on a scale and a fine needle put through it and inserted in the sheet at the station. The scale can thus be swung around in a circle. If the protractor is graduated from 0 to 360 the angle readings in the field are used. If it is graduated into quadrants then the calculated magnetic bearings are used.

First the bearing is called off and the scale swung to it. Then the horizontal distance is called off and platted. Next the total elevation above datum is marked at the point. After all the shots from that station are platted the protractor is shifted to the next.

In working in the field a reading is taken to a new station and carefully read. Vernier "B" is also read when the station reading is made. The last entry at the old station is the one to the forward station. The instrument is carried to the forward station, vernier "A" is set at the reading found for vernier "B" at the station just left and the backsight taken. The rod reading should be the same as the forward reading but the sign of the vertical angle will be different. If the reading does not agree calculate what the difference will amount to and act as seems best. Usually there will be a slight difference and a mean of the two readings will give an accuracy that will be as close as one requires for such work. The first entry at the new station is the check reading to the old. The telescope is not reversed as the above description shows.

In shifting the protractor on the map the procedure imitates closely the field method. Through each station point two lines are drawn at right angles and the protractor fitted to them.

Sometimes it is well within the limits of accuracy to plot station points as side shots are plotted. Generally it is best to make a traverse survey set of notes of the stations polygon and plat it by latitudes and departures. Errors will then be confined to each station point and will not be cumulative. If that is not done it is well to plat the stations polygon in any convenient way before plotting the side shots. If errors have crept in on the lines they can be adjusted before a lot of work has been done.

When carefully done the limit of error will be well within the limits of plotting. An error of 1 : 900 is not particularly good work in running the polygon. It should be nearer 1 : 1500 or 1 : 2000 and can be readily attained without much loss of time. As wire intervals sometimes change a steel tape should be carried and once in a while a line should be measured with the tape and checked with the stadia rod. If the wires are adjustable then adjust them. If they are fixed wires, merely make a note of the new interval and remember it when making the calculations in the office.

An engineer in private practice does not need an umbrella, a recorder, an observer, etc. He can do all the work himself with one or two active intelligent rodmen, using a self reading leveling rod or a specially made stadia rod. Several firms in the United States make good patterns of stadia rods on wood and some make them on a tough oiled painted paper to be glued on a board. A few make them on canvas to be tacked on a board. The writer has used several such rods of different patterns and they were all good. Generally he uses one of his own pattern as illustrated.

It is made from ten to fifteen feet long in sections with hinges on the back so it folds into short lengths. On each side is a common door bolt at each joint to hold it straight when extended. A line is scribed down the back from top to bottom and a point is marked on the back at the bottom to show the rodman when it is on a point. There is a nail here to protect the foot. The rodman either carries a rod level to insure the verticality of the rod or has a small plumb bob hung on the back. He stands directly behind

the rod and is careful not to permit his hands to obscure a sight of any part of the rod.

When the instrument man sets up his instrument he measures the height from the ground to the telescope axis and directs the

STADIA ROD.

Each device represents one-tenth of a foot.

Even tenths on right. Odd tenths on left. No figures.

Horizontal ruling represents black. Diagonal ruling, red.

Red diamond at half foot mark.

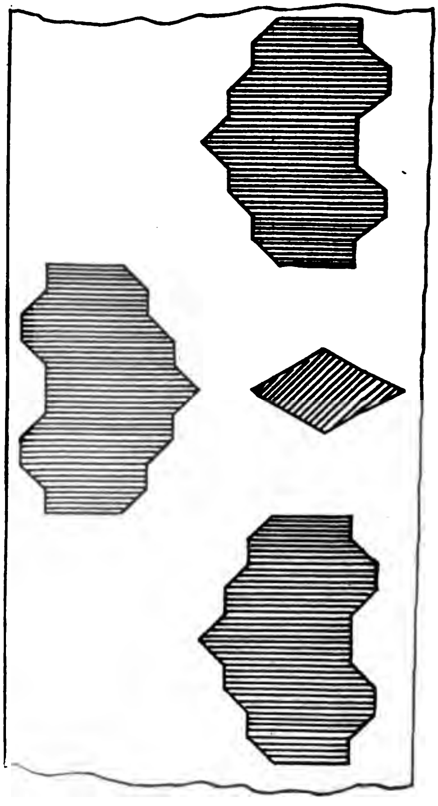
Black numbers, one-tenth high, at each even foot.

Red numbers, one-tenth high, at each odd foot.

Numbers are in space opposite device.

With this rod the nearest foot can be read on short sights and closely estimated on others.

Every reading is made on a corner as well as on a point which is advantageous at different hours of the day.



middle cross wire to that height on the rod for each sight. He reads, however, only the upper and lower stadia wires. For work requiring long sights and great accuracy is not required, an ordinary level rod can be used and held upside down by the rodman. The

upper wire is then directed to the top of the rod and the lower wire gives the direct rod reading without any figuring, mental or otherwise. It takes very little practice to become proficient in reading an inverted rod.

A specific use for the stadia is when a city council wishes grades recommended on certain streets and the time is limited. A stadia survey can be made in a very short time and a profile platted from the contour map sufficiently accurate for the intended purpose. The writer has often done this.

The stadia offers an excellent means of surveying a tract of land for grading estimates. This, however, is treated in text books on surveying.

With a good transit in good adjustment having a well divided vertical arc, elevations can be taken that check wonderfully close with a level.

The writer at first triangulated a tract of land he proposed surveying by the stadia method and determined his instrument points, or at least enough for control. He no longer does this except on a very extensive survey. He also ran levels with a wye or dumpy level and established benches and turning points. He seldom does this any more, for the angular elevations check so well that the time might as well be saved. If his elevations do not close reasonably when his work is completed he will go out with a level and get the exact elevations on the stations and use them, thus confining his errors to each station. In calculating his elevations in the office he first carries them through from station to station and checks on the starting point, where the field work of course closes. Any error within allowable limits is then distributed over the stations in proportion to the lengths between them and these corrected elevations used in computing the side shots.

GENERAL NOTES.

No city engineer should be content with a limit of error in measuring, exceeding 1 : 5000, practically one foot in a mile. That is really too great, for good work done should approximate 1 : 10,000. For long lines the writer prefers to measure on the slope to tack heads so that the tape is thus supported its entire length. This eliminates the error due to sag and miscalculation

as to level of tape. Errors may creep in when calculating but care must be taken to guard against them.

There are a number of formulas for correction of sag, etc. If an engineer wishes to apply them he can do so but it is easy to remember that the correction of sag in an ordinary tape is practically equal to 0.25 of an inch times the length measured in feet. Subtract this from the measurement, for the correction due to sag on an ordinary 100-foot tape is 0.25 of an inch. If no correction is made for sag the tape will be short and consequently the distance recorded will be greater than the true distance.

The expansion per unit of length for one degree rise in temperature or the contraction of one degree fall in temperature is 0.000006. The standard temperature is 60°. The difference in temperature between the standard and that at which the measurement is made, multiplied by the length in feet times 0.000006 gives the correction for temperature.

The normal pull on a tape at which the most uniform results will be obtained varies from ten pounds for fifty feet length to sixteen pounds for one hundred feet. It is a good idea to write the maker when a new tape is purchased and obtain all the information he will give in regard to normal tension, etc., for the tape.

A discussion last year in Engineering News developed the fact that there are several ways of doing simple things. An inquirer asked for the best method of surveying a street for the purpose of locating accurately the buildings on each side.

One method recommended was to run a line approximately down the center of the street and set transit points 200 feet apart. Each point is occupied in succession and with a 100-foot tape as many corners as possible are measured to, the angles to the points being taken at the same time with the transit. For wide streets with the houses set far back, each corner is located by angles (without taping), from at least two transit points. This approximates the plane table method. As houses are built with square corners a sketch is made of each ground plan and all the measurements taken. The two front corners are plotted from the survey and the buildings drawn in from the measurements on the sketches.

Another method was to measure a base line on one side of the street close to the fence and set stations 100 feet apart. Set the

transit on each and turn a right angle across the street and measure across to set a base line on that side. The stations are all numbered. After completing the transit work measure on each base line, marking the plus for each fence corner and opposite each house corner. Measure from the plus the right angle distance to the house corner. Record this in the form of a fraction in white chalk on each object, the numerator being the plus and the denominator being the right angle distance from the base line. The engineer follows the men making the measurements and makes his sketches and such other measurments as are necessary. In this method no diagonal measurements are made.

A third method was similar to the first, but two base lines were run. One was in front to get all the front fences and corners of buildings and the other in the rear of the lots to get the back corners.

In the course of his experience in city work the writer has had to make a number of such surveys. Sometimes it was while in the employ of other men and acting under their instructions. He has therefore used each of the above methods and his preference is for the first. He considers it the neatest and most expeditious, both in field and office.

If the nearest foot is close enough (and it generally is), a stadia survey will do the work with the fewest men and in the shortest time. More data is apt to be collected also, for the method is so simple and easy.

The following matter which appeared in Engineering-Contracting, May 13, 1908, under the heading "Letters to the Editors," will be found useful when dealing with the relocation of curved boundaries:

TABLE FOR RELOCATION OF CURVED BOUNDARIES.

Editor Engineering-Contracting: "In "Engineering News" of March 12 some one signing himself "H. H. T." gave a table to be used in the relocation of curved boundaries for lots when all the stakes had disappeared, or in which only the radius and lot corners were given. The table gave deflections for chord lengths = R/100, R/50, R/33⅓, R/25 and R/20. The writer here presents a table including also R/10.

H. H. T. obtained the deflection angle by the formula d =

$\frac{c/2}{R}$ in which c = chord length (ratio of R) and R = radius of curve. The table given was not absolutely correct for the reason that H. H. T. used a three or four place table and the deflection for R/100 he gave as being 0° 17′ 07.25″. By using a seven place table the result is 0° 17′ 11.33″. In actual use, however, the difference is negligible in even a long curve. The ingenuity of the idea strikes the attention and it is to be regretted that H. H. T. preferred to hide his identity. To run out a curve it is simply necessary to set the instrument on one stake, A, sight to the other, B, plate clamped at zero, and measure chords and deflect from B towards A. He stated that for setting out curbs, sidewalks, etc., he found a chord length of R/25 gave the best results, while for grading R/10 was sufficiently accurate.

In "Engineering News" of April 24 is a letter from Mr. J. Calvin Locke, objecting to the table for the reason that the deflection for 18 stations (to take an example) of chord lengths, = R/100, is not exactly the deflection for 9 stations of chord lengths = R/50. He then proceeds to give a table that is mathematically accurate, I presume, but is not so valuable for the purpose intended as the table of the modest H. H. T. The reason is that the transit used by the average engineer generally reads to minutes, while only a few high priced transits read to 20 and 30 seconds. The differences in the deflections for the different radii are as shown in the following table computed by the writer:

R = 100c	c = 1	d = 0° 17′ 11.33″	30 stations,	$\Delta/2$ = 8° 35′ 39.90″.
R = 50c	c = 2	d = 0° 34′ 22.77″	15 stations,	$\Delta/2$ = 8° 35′ 41.55″.
R = 33⅓c	c = 3	d = 0° 51′ 34.20″	10 stations,	$\Delta/2$ = 8° 35′ 42″.
R = 25c	c = 4	d = 1° 08′ 45.73″	7 stations,	$\Delta/2$ = 8° 01′ 20.11″.
R = 20c	c = 5	d = 1° 25′ 57.35″	6 stations,	$\Delta/2$ = 8° 35′ 44.1″,
R = 10c	c = 10	d = 2° 51′ 57.68″	3 stations,	$\Delta/2$ = 8° 35′ 53.04″.

Taking, for example, the deflection for 30 stations with c = R/100, and using the same angle for 3 stations with c = R/10, the difference in angle amounts to a trifle over 13″, which even the most particular man will say is correct enough for all practical purposes. We cannot split hairs over deflections involving fractions of seconds when using a transit that is considered high grade if it reads to 10 seconds. If we also consider c = 5 ft., R = 500 ft., the difference in location of the tack point will be so small that it is negligible.

In addition to the fact that H. H. T. gave the unit deflection for R = 100 c as being 0 17′ 07.25″ when it is really 0 17′ 11.33″ his table as printed contained a few errors which evidently occurred in the copy or proof reading, as the total additions seem to be correct, so the writer hopes you will publish the following table, which follows the arrangement of H. H. T., as the writer considers it the best form to use in the back of a field book:

DEFLECTION ANGLES FOR CURVES.

	When R = 100c, etc.					
Deflection.	100c	50c	33⅓c	25c	20c	10c
0° 17′ 11.33″	1	..	..	..	..	..
0° 34′ 22.66″	2	1	..	..	..	..
0° 51′ 33.99″	3	..	1	..	..	..
1° 08′ 45.32″	4	2	..	1	..	..
1° 25′ 56.65″	5	..	..	..	1	..
1° 43′ 07.98″	6	3	2	..	..	..
2° 00′ 19.31″	7	..	..	..	..	..
2° 17′ 30.64″	8	4	..	2	..	..
2° 34′ 41.97″	9	..	3	..	..	..
2° 51′ 53.30″	10	5	..	..	2	1
3° 09′ 04.63″	11	..	..	..	..	..
3° 26′ 15.96″	12	6	4	3	..	..
3° 43′ 27.29″	13	..	..	..	..	..
4° 00′ 38.62″	14	7	..	..	..	..
4° 17′ 49.95″	15	..	5	..	3	..
4° 35′ 01.28″	16	8	..	4	..	..
4° 52′ 12.61″	17	..	..	..	..	..
5° 09′ 23.94″	18	9	6	..	..	..
5° 26′ 35.27″	19	..	..	..	..	..
5° 43′ 46.60″	20	10	..	5	4	2
6° 00′ 57.93″	21	..	7	..	..	..
6° 18′ 09.26″	22	11	..	..	..	..
6° 35′ 20.59″	23	..	..	..	..	..
6° 52′ 31.92″	24	12	8	6	..	..
7° 09′ 43.35″	25	..	..	..	5	..
7° 25′ 54.58″	26	13	..	..	..	..
7° 44′ 05.91″	27	..	9	..	..	..
8° 01′ 17.24″	28	14	..	7	..	..
8° 18′ 28.57″	29	..	..	..	..	..
8° 35′ 39.90″	30	15	10	..	6	3

It may be said with respect to the above table that the engineer will seldom have as many as 30 stations to run out even with c = R/100. The value of c will seldom be less than 5 ft. and as lots are hardly ever more than 100 ft. wide and are generally less than 50 ft., it may be seen that the table is extended enough to be very useful. For other values of the ratio R/c the table of Mr. Locke may be used.

Yours truly,

ERNEST McCULLOUGH.

Chicago, Ill., April 24, 1908.

CHAPTER XIV.

ENGINEERING DATA.

In this chapter the writer proposes to place a lot of odds and ends of material that he trusts will be of value. He will appreciate very much all assistance his readers will give in the future to make the chapters on Office Work, Field Work and Engineering Data more valuable in later editions. Copies of special reports, good ordinances, forms of procedure, plats, formulas, etc., are especially wanted. Their receipt will be acknowledged and due credit given if used.

MENSURATION.

Several pages are here given of formulas useful in mensuration and trigonometrical calculations. A table of logarithms is useful when the formulas are complicated, for partial results do not have to be taken into account, as may be seen by performing an example in proportion by the help of logarithms.

The tables of natural sines, cosines, tangents, etc., represent the functions of angles mentioned on the upper half of the page containing the Solution of Right-Angled Triangles, with a radius equal to unity. To use them the function is taken directly from the table and multiplied or divided or added and subtracted. Logarithmic tables of functions are tables of the logarithms corresponding to these numbers. Although the values are only given to each ten minutes of arc these tables will frequently be found useful.

The two pages giving weights and gauges of steel will be useful for reinforced concrete designing.

MENSURATION.

$\pi=3.1415926536$

$\frac{\pi}{2}=1.5708$

$\frac{\pi}{3}=1.0472$

$\frac{\pi}{4}=0.7854$

$\frac{\pi}{12}=0.2618$

$\frac{\pi}{64}=0.04909$

$\frac{1}{\pi}=0.31831$

$\frac{1}{\pi^2}=0.10132$

$\pi^2=9.86960$

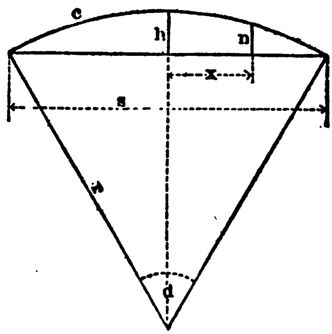
$\pi^3=31.00628$

log. $\pi=0.4971499$

$\sqrt{\pi}=1.77245$

$\sqrt{\frac{1}{\pi}}=0.56419$

log. $\sqrt{\pi}=0.2485749$



$$r=\frac{h^2+\frac{s^2}{4}}{2h}$$

or very nearly $=\frac{s^2}{8h}$

$$n=\sqrt{r^2-x^2}-(r-h)$$

$$h=r-\sqrt{r^2-\frac{s^2}{4}}$$

or very nearly $=\frac{s^2}{8r}$

$$c=a\ 2\ r\ 0{,}008727$$

Circle.

A = area. r = radius.
d = diameter. V = contents.

$A=\frac{\pi\times d^2}{4}=0.7854\ d^2$ $d=1{,}12838\sqrt{A}$

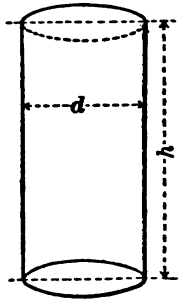
Area.

Sector of Circle = length of arc $\times$ half radius.

Segments of Circle = area of sector less triangle, also for flat segments very nearly $=\frac{4h}{3}\sqrt{0.388h^2+\frac{s^2}{4}}$

—JONES & LAUGHLIN HAND BOOK.

MENSURATION—Continued.



Cylinder.

$$A=\pi\, d\, h+\left[\frac{\pi\, d^2}{4}\right]2$$

$$V=\frac{\pi\, d^2}{4}\,\mathrm{h}$$

Sphere.

$$A=\pi\, d^2 \qquad V=\frac{\pi\, d^3}{6}$$

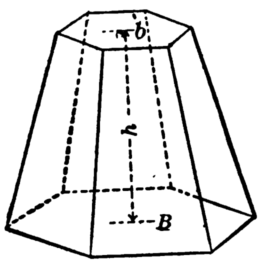
Pyramid and Cone.

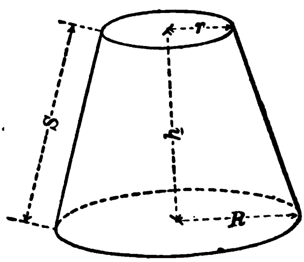
A=periphery or circumference of base $\times$ half slant height.
V=area of base + ⅓ perpendicular height.

Frustum.

A=sum of peripheries or circumferences of the two ends $\times$ half slant height + area of both ends.

Frustum of a cone. $V=\frac{1}{3}\pi\, h\,(R^2+r^2+Rr)$





Frustum of pyramid. $V=\frac{1}{3}\, h\,(B+\sqrt{Bb}+b)$
(h being the distance of the two parallel end surfaces B and b.)

—JONES & LAUGHLIN HAND BOOK.

MENSURATION—Continued.

Triangle.

$$A=\sqrt{s\times(s-a)\ (s-b)\ (s-c)}$$

if s half of the sum of the sides a, b, and c,
or $=$ base $\times$ half perpendicular height.

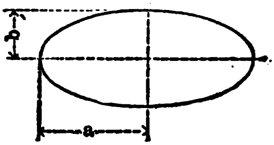
Polygons.

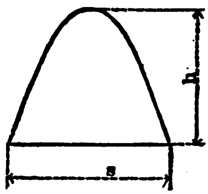
Area of any irregular polygon can be found by dividing the polygon into triangles and take the sum of the triangles' area. Area of any regular polygon

$$=\frac{\text{No. of sides}}{2}\times(\text{circumscribed rad.})^2\times\sin.\frac{2\pi}{\text{No. sides.}}$$

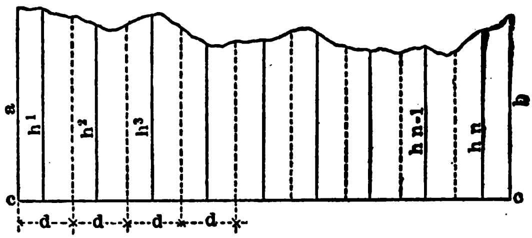
Parabola. $A=\frac{2}{3}\,s\,h$

Ellipse. $A=\pi\,a\,b$





*Area of any Irregular Plane Surface.



Divide the surface into any number, say n, parallel strips of equal widths, d, whose middle ordinates are represented by

$$h_1\ h_2\ h_3\ h_4 \ldots\ldots\ldots\ldots h_{n-1}\ h_n$$

then is, after Poncelet's rule,

$$A=d\,\Sigma\,h+\tfrac{1}{12}\,d\,(a-h_1)+\tfrac{1}{12}\,d\,(b-h_n)$$

but more exact after Francke's rule,

$$A=d\,\Sigma\,h+\tfrac{1}{12}\,d\,(8\,a+h_2-9h_1)+\tfrac{1}{12}\,d\,(8\,b+h_{n-1}-9\,h_n)$$

—JONES & LAUGHLIN HAND BOOK.

MENSURATION—Continued.

Properties of the Circle.

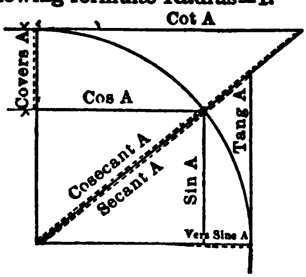
Circumference = Diam. × 3.1416 or $3\frac{1}{7}$.
Diam. × .8862 = Side of an equal square.
Diam. × .7071 = " inscribed "
Diam.^{2} × .7854 = Area of circle.
Radius × 6.2832 = Circumference.
Circumference = $3.5446\sqrt{\text{area of circle.}}$
Diam. = $1.1283\sqrt{\text{area of circle.}}$
Length of arc = No. of degrees × .017453 radius.
Degrees in arc whose length equals radius = 57° 2958.
Length of an arc of 1° = Radius × .017453.
" " " 1′ = Radius × .0002909.
" " " 1″ = Radius × .0000048.
π = Proportion of circumference to diam. = 3.1415926.
$\pi^2 = 9.8696044$.
$\sqrt{\pi} = 1.7724538$.
Log. π = 0 4971499.
$\frac{1}{\pi} = 0.3183001$.
$\frac{1}{360} = .002778$.
$\frac{360}{\pi} = 114.59$.

Trigonometrical Formulæ.

General Equivalents.

The diagram shows the different trigonometrical expressions in terms of the angle *A*.

In the following formulæ Radius = 1.



—JONES & LAUGHLIN HAND BOOK.

MENSURATION—Continued.

Complement of an angle=its difference from 90°.
Supplement of an angle=its difference from 180°

$$\text{Sin.}=\frac{1}{\text{cosec.}}=\frac{\text{cos.}}{\text{cot.}}=\sqrt{(1-\text{cos.}^2)}$$

$$\text{Tan.}=\frac{\text{sin.}}{\text{cos.}}=\frac{1}{\text{cot.}}$$

$$\text{Sec.}=\sqrt{\text{Rad}^2+\text{tan}^2}=\frac{1}{\text{cos.}}=\frac{\text{tan.}}{\text{sin.}}$$

$$\text{Cos.}=\sqrt{(1-\text{sin.}^2)}=\frac{\text{sin.}}{\text{tan.}}=\text{sin.}\times\text{cot.}=\frac{1}{\text{sec.}}$$

$$\text{Cot.}=\frac{\text{cos.}}{\text{sin.}}=\frac{1}{\text{tan.}}\qquad \text{Cosec.}=\frac{1}{\text{sin.}}$$

Versin. = Rad.—cos. Coversin. = Rad.—Sin.

$$\text{Rad.}=\text{tan.}\times\text{cot.}=\sqrt{\text{sin.}^2+\text{cos.}^2}$$

Solution of Right-Angled Triangles.

$$\text{Hypoth.}^2=\text{base}^2+\text{perpend.}^2$$
$$\text{Base}^2=(\text{hyp.}+\text{perp.})\times(\text{hyp.}-\text{perp.})$$
$$\text{Perp.}^2=(\text{hyp.}+\text{base})\times(\text{hyp.}-\text{base}).$$

$$\text{Sin.}=a\,\frac{A}{C}\qquad \text{Cot. } a=\frac{B}{A}$$

$$\text{Cos. } a=\frac{B}{C}\qquad \text{Cos. } b=\frac{A}{C}$$

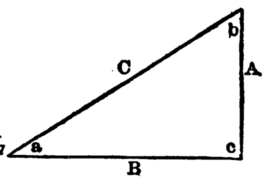
$$\text{Tan. } a=\frac{A}{B}\qquad \text{Cot. } b=\frac{A}{B}$$

$$\text{Cosec. } a=\frac{C}{A}\qquad b=90°-a$$

$$\text{Sec. } a=\frac{C}{B}\qquad A=B\text{ tan. } a\qquad A=C\text{ sin. } a$$

$$B=C\text{ cos. } a=A\text{ cot. } a=\sqrt{(C+A)(C-A)}$$

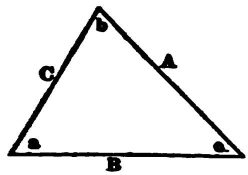
$$C=\sqrt{A^2+B^2}=\frac{A}{\text{sin. } a}=\frac{B}{\text{cos. } a}$$



—JONES & LAUGHLIN HAND BOOK.

MENSURATION—Continued.

Solution of Oblique-Angled Triangles.



Value of any side C is:

$$C=\frac{A\ \sin.\ c}{\sin.\ a}=\frac{B\ \sin.\ c}{\sin.\ b}=\frac{A}{\cos.\ b+\sin.\ b\ \cot.\ c}$$

$$C=\frac{B}{\cos.\ a+\sin.\ a\ \cot.\ c}=A\ \cos.\ b+A$$

$$C=\sqrt{A^2+B^2-2A\ B\cos.\ c}=$$

$$B\cos.\ a+B\ \sin.\ a\ \cot.\ b$$

Value of any angle a is:

$$\text{Sin. } a=\frac{A\ \sin.\ c}{c}=\frac{A\ \sin.\ b}{B}=\sin.\ (b+c)$$

$$\text{Sin. } a=\sin.\ b\ \cos.\ c+\cos.\ b\ \sin.\ c$$

$$\text{Cos. } a=\sin.\ b\ \sin.\ c-\cos.\ b\ \text{Cos. } c$$

$$\text{Cos. } a=\frac{C^2+B^2-A^2}{2\,B\,C}$$

$$\text{Tan. } a=\frac{A\ \sin.\ c}{B-A\ \cos.\ c}=\frac{A\ \sin.\ b}{C-A\ \cos.\ b}$$

$$\text{Tan. } a=\frac{\tan.\ b+\tan.\ c}{\tan.\ b\ \text{n.}c\ \text{at}-1}$$

—JONES & LAUGHLIN HAND BOOK.

Degrees	TANGENT							
	0′	10′	20′	30′	40′	50′	60′	
0	0.00000	0.00291	0.00582	0.00873	0.01164	0.01455	0.01746	89
1	0.01746	0.02036	0.02328	0.02619	0.02910	0.03201	0.03492	88
2	0.03492	0.03783	0.04075	0.04366	0.04658	0.04949	0.05241	87
3	0.05241	0.05533	0.05824	0.06116	0.06408	0.06700	0.06993	86
4	0.06993	0.07285	0.07578	0.07870	0.08163	0.08456	0.08749	85
5	0.08749	0.09042	0.09335	0.09629	0.09923	0.10216	0.10510	84
6	0.10510	0.10805	0.11099	0.11394	0.11688	0.11983	0.12278	83
7	0.12278	0.12574	0.12869	0.13165	0.13461	0.13758	0.14054	82
8	0.14054	0.14351	0.14648	0.14945	0.15243	0.15540	0.15838	81
9	0.15838	0.16137	0.16435	0.16734	0.17033	0.17333	0.17633	80
10	0.17633	0.17933	0.18233	0.18534	0.18835	0.19136	0.19438	79
11	0.19438	0.19740	0.20042	0.20345	0.20648	0.20952	0.21256	78
12	0.21256	0.21560	0.21864	0.22169	0.22475	0.22781	0.23087	77
13	0.23087	0.23393	0.23700	0.24008	0.24316	0.24624	0.24933	76
14	0.24933	0.25242	0.25552	0.25862	0.26172	0.26483	0.26795	75
15	0.26795	0.27107	0.27419	0.27732	0.28046	0.28360	0.28675	74
16	0.28675	0.28990	0.29305	0.29621	0.29938	0.30255	0.30573	73
17	0.30573	0.30891	0.31210	0.31530	0.31850	0.32171	0.32492	72
18	0.32492	0.32814	0.33136	0.33460	0.33783	0.34108	0.34433	71
19	0.34433	0.34758	0.35085	0.35412	0.35740	0.36068	0.36397	70
20	0.36397	0.36727	0.37057	0.37388	0.37720	0.38053	0.38386	69
21	0.38386	0.38721	0.39055	0.39391	0.39727	0.40065	0.40403	68
22	0.40403	0.40741	0.41081	0.41421	0.41763	0.42105	0.42447	67
23	0.42447	0.42791	0.43136	0.43481	0.43828	0.44175	0.44523	66
24	0.44523	0.44872	0.45222	0.45573	0.45924	0.46277	0.46631	65
25	0.46631	0.46985	0.47341	0.47698	0.48055	0.48414	0.48773	64
26	0.48773	0.49134	0.49495	0.49858	0.50222	0.50587	0.50953	63
27	0.50953	0.51320	0.51688	0.52057	0.52427	0.52798	0.53171	62
28	0.53171	0.53545	0.53920	0.54296	0.54674	0.55051	0.55431	61
29	0.55431	0.55812	0.56194	0.56577	0.56962	0.57348	0.57735	60
30	0.57735	0.58124	0.58513	0.58905	0.59297	0.59691	0.60086	59
31	0.60086	0.60483	0.60881	0.61280	0.61681	0.62083	0.62487	58
32	0.62487	0.62892	0.63299	0.63707	0.64117	0.64528	0.64941	57
33	0.64941	0.65355	0.65771	0.66189	0.66608	0.67028	0.67451	56
34	0.67451	0.67875	0.68301	0.68728	0.69157	0.69588	0.70021	55
35	0.70021	0.70455	0.70891	0.71329	0.71769	0.72211	0.72654	54
36	0.72654	0.73100	0.73547	0.73996	6.74447	0.74900	0.75355	53
37	0.75355	0.75812	0.76272	0.76733	0.77196	0.77661	0.78129	52
38	0.78129	0.78598	0.79070	0.79544	0.80020	0.80498	0.80978	51
39	0.80978	0.81461	0.81946	0.82434	0.82923	0.83415	0.83910	50
40	0.83910	0.84407	0.84906	0.85408	0.85912	0.86419	0.86929	49
41	0.86929	0.87441	0.87955	0.88473	0.88992	0.89515	0.90040	48
42	0.90040	0.90569	0.91099	0.91633	0.92170	0.92709	0.93252	47
43	0.93252	0.93797	0.94345	0.94896	0.95451	0.96008	0.96569	46
44	0.96569	0.97133	0.97700	0.98270	0.98843	0.99420	1.00000	45
	60′	50′	40′	30′	20′	10′	0′	Degrees
	COTANGENT							

—CARNEGIE HAND BOOK.

Degrees	COTANGENT 0′	10′	20′	30′	40′	50′	60′	
0	∞	343.77371	171.88540	114.58865	85.93979	68.75009	57.28996	89
1	57.28996	49.10388	42.96408	38.18846	34.36777	31.24158	28.63625	88
2	28.63625	26.43160	24.54176	22.90377	21.47040	20.20555	19.08114	87
3	19.08114	18.07498	17.16934	16.34986	15.60478	14.92442	14.30067	86
4	14.30067	13.72674	13.19688	12.70621	12.25051	11.82617	11.43005	85
5	11.43005	11.05943	10.71191	10.38540	10.07803	9.78817	9.51436	84
6	9.51436	9.25530	9.00983	8.77689	8.55555	8.34496	8.14435	83
7	8.14435	7.95302	7.77035	7.59575	7.42871	7.26873	7.11537	82
8	7.11537	6.96823	6.82694	6.69116	6.56055	6.43484	6.31375	81
9	6.31375	6.19703	6.08444	5.97576	5.87080	5.76937	5.67128	80
10	5.67128	5.57638	5.48451	5.39552	5.30928	5.22566	5.14455	79
11	5.14455	5.06584	4.98940	4.91516	4.84300	4.77286	4.70463	78
12	4.70463	4.63825	4.57363	4.51071	4.44942	4.38969	4.33148	77
13	4.33148	4.27471	4.21933	4.16530	4.11256	4.06107	4.01078	76
14	4.01078	3.96165	3.91364	3.86671	3.82083	3.77595	3.73205	75
15	3.73205	3.68909	3.64705	3.60588	3.56557	3.52609	3.48741	74
16	3.48741	3.44951	3.41236	3.37594	3.34023	3.30521	3.27085	73
17	3.27085	3.23714	3.20406	3.17159	3.13972	3.10842	3.07768	72
18	3.07768	3.04749	3.01783	2.98869	2.96004	2.93189	2.90421	71
19	2.90421	2.87700	2.85023	2.82391	2.79802	2.77254	2.74748	70
20	2.74748	2.72281	2.69853	2.67462	2.65109	2.62791	2.60509	69
21	2.60509	2.58261	2.56046	2.53865	2.51715	2.49597	2.47509	68
22	2.47509	2.45451	2.43422	2.41421	2.39449	2.37504	2.35585	67
23	2.35585	2.33693	2.31826	2.29984	2.28167	2.26374	2.24604	66
24	2.24604	2.22857	2.21132	2.19430	2.17749	2.16090	2.14451	65
25	2.14451	2.12832	2.11233	2.09654	2.08094	2.06553	2.05030	64
26	2.05030	2.03526	2.02039	2.00569	1.99116	1.97680	1.96261	63
27	1.96261	1.94858	1.93470	1.92098	1.90741	1.89400	1.88073	62
28	1.88073	1.86760	1.85462	1.84177	1.82907	1.81649	1.80405	61
29	1.80405	1.79174	1.77955	1.76749	1.75556	1.74375	1.73205	60
30	1.73205	1.72047	1.70901	1.69766	1.68643	1.67530	1.66428	59
31	1.66428	1.65337	1.64256	1.63185	1.62125	1.61074	1.60033	58
32	1.60033	1.59002	1.57961	1.56969	1.55966	1.54972	1.53987	57
33	1.53987	1.53010	1.52043	1.51084	1.50133	1.49190	1.48256	56
34	1.48256	1.47330	1.46411	1.45501	1.44598	1.43703	1.42815	55
35	1.42815	1.41934	1.41061	1.40195	1.39336	1.38484	1.37638	54
36	1.37638	1.36800	1.35968	1.35142	1.34323	1.33511	1.32704	53
37	1.32704	1.31904	1.31110	1.30323	1.29541	1.28764	1.27994	52
38	1.27994	1.27230	1.26471	1.25717	1.24969	1.24227	1.23490	51
39	1.23490	1.22758	1.22031	1.21310	1.20593	1.19882	1.19175	50
40	1.19175	1.18474	1.17777	1.17085	1.16398	1.15715	1.15037	49
41	1.15037	1.14363	1.13694	1.13029	1.12369	1.11713	1.11061	48
42	1.11061	1.10414	1.09770	1.09131	1.08496	1.07864	1.07237	47
43	1.07237	1.06613	1.05994	1.05378	1.04766	1.04158	1.03553	46
44	1.03553	1.02952	1.02355	1.01761	1.01170	1.00583	1.00000	45
	60′	50′	40′	30′	20′	10′	0′ TANGENT	Degrees

—CARNEGIE HAND BOOK.

Degrees	Sine							
	0′	10′	20′	30′	40′	50′	60′	
0	0.00000	0.00291	0.00582	0.00873	0.01164	0.01454	0.01745	89
1	0.01745	0.02036	0.02327	0.02618	0.02908	0.03199	0.03490	88
2	0.03490	0.03781	0.04071	0.04362	0.04653	0.04943	0.05234	87
3	0.05234	0.05524	0.05814	0.06105	0.06395	0.06685	0.06976	86
4	0.06976	0.07266	0.07556	0.07846	0.08136	0.08426	0.08716	85
5	0.08716	0.09005	0.09295	0.09585	0.09874	0.10164	0.10453	84
6	0.10453	0.10742	0.11031	0.11320	0.11609	0.11898	0.12187	83
7	0.12187	0.12476	0.12764	0.13053	0.13341	0.13629	0.13917	82
8	0.13917	0.14205	0.14493	0.14781	0.15069	0.15356	0.15643	81
9	0.15643	0.15931	0.16218	0.16505	0.16792	0.17078	0.17365	80
10	0.17365	0.17651	0.17937	0.18224	0.18509	0.18795	0.19081	79
11	0.19081	0.19366	0.19652	0.19937	0.20222	0.20507	0.20791	78
12	0.20791	0.21076	0.21360	0.21644	0.21928	0.22212	0.22495	77
13	0.22495	0.22778	0.23062	0.23345	0.23627	0.23910	0.24192	76
14	0.24192	0.24474	0.24756	0.25038	0.25320	0.25601	0.25882	75
15	0.25882	0.26163	0.26443	0.26724	0.27004	0.27284	0.27564	74
16	0.27564	0.27843	0.28123	0.28402	0.28680	0.28959	0.29237	73
17	0.29237	0.29515	0.29793	0.30071	0.30348	0.30625	0.30902	72
18	0.30902	0.31178	0.31454	0.31730	0.32006	0.32282	0.32557	71
19	0.32557	0.32832	0.33106	0.33381	0.33655	0.33929	0.34202	70
20	0.34202	0.34475	0.34748	0.35021	0.35293	0.35565	0.35837	69
21	0.35837	0.36108	0.36379	0.36650	0.36921	0.37191	0.37461	68
22	0.37461	0.37730	0.37999	0.38268	0.38537	0.38805	0.39073	67
23	0.39073	0.39341	0.39608	0.39875	0.40142	0.40408	0.40674	66
24	0.40674	0.40939	0.41204	0.41469	0.41734	0.41998	0.42262	65
25	0.42262	0.42525	0.42788	0.43051	0.43313	0.43575	0.43837	64
26	0.43837	0.44098	0.44359	0.44620	0.44880	0.45140	0.45399	63
27	0.45399	0.45658	0.45917	0.46175	0.46433	0.46690	0.46947	62
28	0.46947	0.47204	0.47460	0.47716	0.47971	0.48226	0.48481	61
29	0.48481	0.48735	0.48989	0.49242	0.49495	0.49748	0.50000	60
30	0.50000	0.50252	0.50503	0.50754	0.51004	0.51254	0.51504	59
31	0.51504	0.51753	0.52002	0.52250	0.52498	0.52745	0.52992	58
32	0.52992	0.53238	0.53484	0.53730	0.53975	0.54220	0.54464	57
33	0.54464	0.54708	0.54951	0.55194	0.55436	0.55678	0.55919	56
34	0.55919	0.56160	0.56401	0.56641	0.56880	0.57119	0.57358	55
35	0.57358	0.57596	0.57833	0.58070	0.58307	0.58543	0.58779	54
36	0.58779	0.59014	0.59248	0.59482	0.59716	0.59949	0.60182	53
37	0.60182	0.60414	0.60645	0.60876	0.61107	0.61337	0.61566	52
38	0.61566	0.61795	0.62024	0.62251	0.62479	0.62706	0.62932	51
39	0.62932	0.63158	0.63383	0.63608	0.63832	0.64056	0.64279	50
40	0.64279	0.64501	0.64723	0.64945	0.65166	0.65386	0.65606	49
41	0.65606	0.65825	0.66044	0.66262	0.66480	0.66697	0.66913	48
42	0.66913	0.67129	0.67344	0.67559	0.67773	0.67987	0.68200	47
43	0.68200	0.68412	0.68624	0.68835	0.69046	0.69256	0.69466	46
44	0.69466	0.69675	0.69883	0.70091	0.70298	0.70505	0.70711	45
	60′	50′	40′	30′	20′	10′	0′	Degrees
	Cosine							

—CARNEGIE HAND BOOK.

Degrees	Cosine							
	0'	10'	20'	30'	40'	50'	60'	
0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	89
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	88
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	87
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	86
4	[illegible]	[illegible]	0.99714	[illegible]	[illegible]	[illegible]	[illegible]	85
5	[illegible]	[illegible]	[illegible]	0.99540	0.99511	[illegible]	[illegible]	84
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	83
7	[illegible]	[illegible]	[illegible]	0.99144	[illegible]	[illegible]	[illegible]	82
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.98814	[illegible]	81
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	79
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.97875	0.97815	78
12	[illegible]	0.97754	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	77
13	[illegible]	0.97371	0.97304	[illegible]	[illegible]	[illegible]	[illegible]	76
14	[illegible]	[illegible]	[illegible]	0.96815	[illegible]	[illegible]	[illegible]	75
15	[illegible]	0.96517	0.96440	[illegible]	[illegible]	[illegible]	0.96126	74
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.95715	[illegible]	73
17	[illegible]	0.95545	[illegible]	0.95372	[illegible]	0.95195	[illegible]	72
18	[illegible]	0.95015	[illegible]	[illegible]	0.94740	[illegible]	0.94552	71
19	0.94552	0.94457	0.94361	0.94264	0.94167	[illegible]	[illegible]	70
20	[illegible]	[illegible]	[illegible]	0.93667	0.93565	[illegible]	0.93358	69
21	0.93358	0.93253	0.93148	0.93042	0.92935	0.92827	0.92718	68
22	0.92718	[illegible]	0.92499	0.92388	0.92276	0.92164	0.92050	67
23	0.92050	0.91936	0.91822	0.91706	0.91590	0.91472	0.91355	66
24	0.91355	0.91236	0.91116	0.90996	0.90875	0.90753	0.90631	65
25	0.90631	0.90507	0.90383	0.90259	0.90133	0.90007	0.89879	64
26	0.89879	0.89752	0.89623	0.89493	0.89363	0.89232	0.89101	63
27	0.89101	0.88968	0.88835	0.88701	0.88566	0.88431	0.88295	62
28	0.88295	0.88158	0.88020	0.87882	0.87743	0.87603	0.87462	61
29	0.87462	0.87321	0.87178	0.87036	0.86892	0.86748	0.86603	60
30	0.86603	0.86457	0.86310	0.86163	0.86015	0.85866	0.85717	59
31	0.85717	0.85567	0.85416	0.85264	0.85112	0.84959	0.84805	58
32	0.84805	0.84650	0.84495	0.84339	0.84182	0.84025	0.83867	57
33	0.83867	0.83708	0.83549	0.83389	0.83228	0.83066	0.82904	56
34	0.82904	0.82741	0.82577	0.82413	0.82248	0.82082	0.81915	55
35	0.81915	0.81748	0.81580	0.81412	0.81242	0.81072	0.80902	54
36	0.80902	0.80730	0.80558	0.80386	0.80212	0.80038	0.79864	53
37	0.79864	0.79688	0.79512	0.79335	0.79158	0.78980	0.78801	52
38	0.78801	0.78622	0.78442	0.78261	0.78079	0.77897	0.77715	51
39	0.77715	0.77531	0.77347	0.77162	0.76977	0.76791	0.76604	50
40	0.76604	0.76417	0.76229	0.76041	0.75851	0.75661	0.75471	49
41	0.75471	0.75280	0.75088	0.74896	0.74703	0.74509	0.74314	48
42	0.74314	0.74120	0.73924	0.73728	0.73531	0.73333	0.73135	47
43	0.73135	0.72937	0.72737	0.72537	0.72337	0.72136	0.71934	46
44	0.71934	0.71732	0.71529	0.71325	0.71121	0.70916	0.70711	45
	60'	50'	40'	30'	20'	10'	0'	Degrees
	Sine							

—CARNEGIE HAND BOOK.

Degrees	SECANTS 0′	10′	20′	30′	40′	50′	60′	
0	1.00000	1.00001	1.00002	1.00004	1.00007	1.00011	1.00015	89
1	1.00015	1.00021	1.00027	1.00034	1.00042	1.00051	1.00061	88
2	1.00061	1.00072	1.00083	1.00095	1.00108	1.00122	1.00137	87
3	1.00137	1.00153	1.00169	1.00187	1.00205	1.00224	1.00244	86
4	1.00244	1.00265	1.00287	1.00309	1.00333	1.00357	1.00382	85
5	1.00382	1.00408	1.00435	1.00463	1.00491	1.00521	1.00551	84
6	1.00551	1.00582	1.00614	1.00647	1.00681	1.00715	1.00751	83
7	1.00751	1.00787	1.00825	1.00863	1.00902	1.00942	1.00983	82
8	1.00983	1.01024	1.01067	1.01111	1.01155	1.01200	1.01247	81
9	1.01247	1.01294	1.01342	1.01391	1.01440	1.01491	1.01543	80
10	1.01543	1.01595	1.01649	1.01703	1.01758	1.01815	1.01872	79
11	1.01872	1.01930	1.01989	1.02049	1.02110	1.02171	1.02234	78
12	1.02234	1.02298	1.02362	1.02428	1.02494	1.02562	1.02630	77
13	1.02630	1.02700	1.02770	1.02842	1.02914	1.02987	1.03061	76
14	1.03061	1.03137	1.03213	1.03290	1.03368	1.03447	1.03528	75
15	1.03528	1.03609	1.03691	1.03774	1.03858	1.03944	1.04030	74
16	1.04030	1.04117	1.04206	1.04295	1.04385	1.04477	1.04569	73
17	1.04569	1.04663	1.04757	1.04853	1.04950	1.05047	1.05146	72
18	1.05146	1.05246	1.05347	1.05449	1.05552	1.05657	1.05762	71
19	1.05762	1.05869	1.05976	1.06085	1.06195	1.06306	1.06418	70
20	1.06418	1.06531	1.06645	1.06761	1.06878	1.06995	1.07115	69
21	1.07115	1.07235	1.07356	1.07479	1.07602	1.07727	1.07853	68
22	1.07853	1.07981	1.08109	1.08239	1.08370	1.08503	1.08636	67
23	1.08636	1.08771	1.08907	1.09044	1.09183	1.09323	1.09464	66
24	1.09464	1.09606	1.09750	1.09895	1.10041	1.10189	1.10338	65
25	1.10338	1.10488	1.10640	1.10793	1.10947	1.11103	1.11260	64
26	1.11260	1.11419	1.11579	1.11740	1.11903	1.12067	1.12233	63
27	1.12233	1.12400	1.12568	1.12738	1.12910	1.13083	1.13257	62
28	1.13257	1.13433	1.13610	1.13789	1.13970	1.14152	1.14335	61
29	1.14335	1.14521	1.14707	1.14896	1.15085	1.15277	1.15470	60
30	1.15470	1.15665	1.15861	1.16059	1.16259	1.16460	1.16663	59
31	1.16663	1.16868	1.17075	1.17283	1.17493	1.17704	1.17918	58
32	1.17918	1.18133	1.18350	1.18569	1.18790	1.19012	1.19236	57
33	1.19236	1.19463	1.19691	1.19920	1.20152	1.20386	1.20622	56
34	1.20622	1.20859	1.21099	1.21341	1.21584	1.21830	1.22077	55
35	1.22077	1.22327	1.22579	1.22833	1.23089	1.23347	1.23607	54
36	1.23607	1.23869	1.24134	1.24400	1.24669	1.24940	1.25214	53
37	1.25214	1.25489	1.25767	1.26047	1.26330	1.26615	1.26902	52
38	1.26902	1.27191	1.27483	1.27778	1.28075	1.28374	1.28676	51
39	1.28676	1.28980	1.29287	1.29597	1.29909	1.30223	1.30541	50
40	1.30541	1.30861	1.31183	1.31509	1.31837	1.32168	1.32501	49
41	1.32501	1.32838	1.33177	1.33519	1.33864	1.34212	1.34563	48
42	1.34563	1.34917	1.35274	1.35634	1.35997	1.36363	1.36733	47
43	1.36733	1.37105	1.37481	1.37860	1.38242	1.38628	1.39016	46
44	1.39016	1.39409	1.39804	1.40203	1.40606	1.41012	1.41421	45
	60′	50′	40′	30′	20′	10′	0′ COSECANTS	Degrees

—CARNEGIE HAND BOOK.

Degrees	COSECANTS 0′	10′	20′	30′	40′	50′	60′	
0	∞	343.77516	171.88831	114.59301	85.94561	68.75736	57.29869	89
1	57.29869	49.11406	42.97571	38.20155	34.38232	31.25758	28.65371	88
2	28.65371	26.45051	24.56212	22.92559	21.49368	20.23028	19.10732	87
3	19.10732	18.10262	17.19842	16.38041	15.63679	14.95788	14.33559	86
4	14.33559	13.76312	13.23472	12.74550	12.29125	11.86837	11.47371	85
5	11.47371	11.10455	10.75849	10.43343	10.12752	9.83912	9.56677	84
6	9.56677	9.30917	9.06515	8.83367	8.61379	8.40466	8.20551	83
7	8.20551	8.01565	7.83443	7.66130	7.49571	7.33719	7.18530	82
8	7.18530	7.03962	6.89979	6.76547	6.63633	6.51208	6.39245	81
9	6.39245	6.27719	6.16607	6.05886	5.95536	5.85539	5.75877	80
10	5.75877	5.66533	5.57493	5.48740	5.40263	5.32049	5.24084	79
11	5.24084	5.16359	5.08863	5.01585	4.94517	4.87649	4.80973	78
12	4.80973	4.74482	4.68167	4.62023	4.56041	4.50216	4.44541	77
13	4.44541	4.39012	4.33622	4.28366	4.23239	4.18238	4.13357	76
14	4.13357	4.08591	4.03938	3.99393	3.94952	3.90613	3.86370	75
15	3.86370	3.82223	3.78166	3.74198	3.70315	3.66515	3.62796	74
16	3.62796	3.59154	3.55587	3.52094	3.48671	3.45317	3.42030	73
17	3.42030	3.38808	3.35649	3.32551	3.29512	3.26531	3.23607	72
18	3.23607	3.20737	3.17920	3.15155	3.12440	3.09774	3.07155	71
19	3.07155	3.04584	3.02057	2.99574	2.97135	2.94737	2.92380	70
20	2.92380	2.90063	2.87785	2.85545	2.83342	2.81175	2.79043	69
21	2.79043	2.76945	2.74881	2.72850	2.70851	2.68884	2.66947	68
22	2.66947	2.65040	2.63162	2.61313	2.59491	2.57698	2.55930	67
23	2.55930	2.54190	2.52474	2.50784	2.49119	2.47477	2.45859	66
24	2.45859	2.44264	2.42692	2.41142	2.39614	2.38107	2.36620	65
25	2.36620	2.35154	2.33708	2.32282	2.30875	2.29487	2.28117	64
26	2.28117	2.26766	2.25432	2.24116	2.22817	2.21535	2.20269	63
27	2.20269	2.19019	2.17786	2.16568	2.15366	2.14178	2.13005	62
28	2.13005	2.11847	2.10704	2.09574	2.08458	2.07356	2.06267	61
29	2.06267	2.05191	2.04128	2.03077	2.02039	2.01014	2.00000	60
30	2.00000	1.98998	1.98008	1.97029	1.96062	1.95106	1.94160	59
31	1.94160	1.93226	1.92302	1.91388	1.90485	1.89591	1.88709	58
32	1.88708	1.87834	1.86990	1.86116	1.85271	1.84435	1.83608	57
33	1.83608	1.82790	1.81981	1.81180	1.80388	1.79604	1.78829	56
34	1.78829	1.78062	1.77303	1.76552	1.75808	1.75073	1.74345	55
35	1.74345	1.73624	1.72911	1.72205	1.71503	1.70815	1.70130	54
36	1.70130	1.69452	1.68782	1.68117	1.67460	1.66809	1.66164	53
37	1.66164	1.65526	1.64894	1.64268	1.63648	1.63035	1.62427	52
38	1.62427	1.61825	1.61229	1.60639	1.60054	1.59475	1.58902	51
39	1.58902	1.58333	1.57771	1.57218	1.56661	1.56114	1.55572	50
40	1.55572	1.55036	1.54504	1.53977	1.53455	1.52938	1.52425	49
41	1.52425	1.51918	1.51415	1.50916	1.50422	1.49933	1.49448	48
42	1.49448	1.48967	1.48491	1.48019	1.47551	1.47087	1.46628	47
43	1.46628	1.46173	1.45721	1.45274	1.44831	1.44391	1.43956	46
44	1.43956	1.43524	1.43096	1.42672	1.42251	1.41835	1.41421	45
	60′	50′	40′	30′	20′	10′	0′	Degrees
	SECANTS							

—CARNEGIE HAND BOOK.

Decimals of a Foot for each 1-64 of an Inch.

Inch.	0"	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"
0	.0	.0833	.1667	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167
1/64	.0013	.0846	.1680	.2513	.3346	.4180	.5013	.5846	.6680	.7513	.8346	.9180
1/32	.0026	.0859	.1693	.2526	.3359	.4193	.5026	.5859	.6693	.7526	.8359	.9193
3/64	.0039	.0872	.1706	.2539	.3372	.4206	.5039	.5872	.6706	.7539	.8372	.9206
1/16	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
5/64	.0065	.0898	.1732	.2565	.3398	.4232	.5065	.5898	.6732	.7565	.8398	.9232
3/32	.0078	.0911	.1745	.2578	.3411	.4245	.5078	.5911	.6745	.7578	.8411	.9245
7/64	.0091	.0924	.1758	.2591	.3424	.4258	.5091	.5924	6758	.7591	.8424	.9258
1/8	.0104	.0937	.1771	.2604	.3437	.4271	.5104	.5937	.6771	.7604	.8437	.9271
9/64	.0117	.0951	.1784	.2617	.3451	.4284	.5117	.5951	.6784	.7617	.8451	.9284
5/32	.0130	.0964	.1797	.2630	.3464	.4297	.5130	.5964	.6797	.7630	.8464	.9297
11/64	.0143	.0977	.1810	.2643	.3477	.4310	.5143	.5977	.6810	.7643	.8477	.9310
3/16	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	.9323
13/64	.0169	.1003	.1836	.2669	.3503	.4336	.5169	.6003	.6836	.7669	.8503	.9336
7/32	.0182	.1016	.1849	.2682	.3516	.4349	.5182	.6016	.6849	.7682	.8516	.9349
15/64	.0195	.1029	.1862	.2695	.3529	.4362	.5195	.6029	.6862	.7695	.8529	.9362
1/4	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375
17/64	.0221	.1055	.1888	.2721	.3555	.4388	.5221	.6055	.6888	.7721	.8555	.9388
9/32	.0234	.1068	.1901	.2734	.3568	.4401	.5234	.6063	.6901	.7734	.8568	.9401
19/64	.0247	.1081	.1914	.2747	.3581	.4414	.5247	.6081	.6914	.7747	.8581	.9414
5/16	.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
21/64	.0273	.1107	.1940	.2773	.3607	.4440	.5273	.6107	.6940	.7773	.8607	.9440
11/32	.0286	.1120	.1953	.2786	.3620	.4453	.5286	.6120	.6953	.7786	.8620	.9453
23/64	.0299	.1133	.1966	.2799	.3633	.4466	.5299	.6133	.6966	.7799	.8633	.9466
3/8	.0312	.1146	.1979	.2812	.3646	.4479	.5312	.6146	.6979	.7212	.8646	.9479
25/64	.0326	.1159	.1992	.2826	.3659	.4492	.5326	.6159	.6992	.7826	.8659	.9492
13/32	.0339	.1172	.2005	.2839	.3672	.4505	.5339	.6172	.7005	.7839	.8672	.9505
27/64	.0352	.1185	.2018	.2852	.3685	.4518	.5352	.6185	.7018	.7852	.8685	.9518
7/16	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	.9531
29/64	.0378	.1211	.2044	.2878	.3711	.4544	.5378	.6211	.7044	.7878	.8711	.9544
15/32	.0391	.1224	.2057	.2891	.3724	.4557	.5391	.6224	.7057	.7891	.8724	.9557
31/64	.0404	.1237	.2070	.2904	.3737	.4570	.5404	.6237	.7070	.7904	.8737	.9570
1/2	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583

—JONES & LAUGHLIN HAND BOOK.

Decimals of a Foot for each 1-64 of an Inch.

Inch.	0"	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"
½	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9533
33/64	.0430	.1263	.2096	.2930	.3763	.4596	.5430	.6263	.7096	.7930	.8763	.9596
17/32	.0443	.1276	.2109	.2943	.3776	.4609	.5443	.6276	.7109	.7943	.8776	.9609
35/64	.0456	.1289	.2122	.2956	.3789	.4622	.5456	.6289	.7122	.7956	.8789	.9622
9/16	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	.8802	.9635
37/64	.0482	.1315	.2148	.2982	.3815	.4648	.5482	.6315	.7148	.7982	.8815	.9648
19/32	.0495	.1328	.2161	.2995	.3828	.4661	.5495	.6328	.7161	.7995	.8828	.9661
39/64	.0508	.1341	.2174	.3008	.3841	.4674	.5508	.6341	.7174	.8008	.8841	.9674
⅝	.0521	.1354	.2188	.3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	.9688
41/64	.0534	.1367	.2201	.3034	.3867	.4701	.5534	.6367	.7201	.8034	.8867	.9701
21/32	.0547	.1380	.2214	.3047	.3880	.4714	.5547	.6380	.7214	.8047	.8880	.9714
43/64	.0560	.1393	.2227	.3060	.3893	.4727	.5560	.6393	.7227	.8060	.8893	.9727
11/16	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740
45/64	.0586	.1419	.2253	.3086	.3919	.4753	.5586	.6419	.7253	.8086	.8919	.9753
23/32	.0599	.1432	.2266	.3099	.3932	.4766	.5599	.6432	.7266	.8099	.8932	.9766
47/64	.0612	.1445	.2279	.3112	.3945	.4779	.5612	.6445	.7279	.8112	.8945	.9779
¾	.0625	.1458	.2292	.3125	.3958	.4792	.5625	.6458	.7292	.8125	.8958	.9792
49/64	.0638	.1471	.2305	.3138	.3971	.4805	.5638	.6471	.7305	.8138	.8971	.9805
25/32	.0651	.1484	.2318	.3151	.3984	.4818	.5651	.6484	.7318	.8151	.8984	.9818
51/64	.0664	.1497	.2331	.3164	.3997	.4831	.5664	.6497	.7331	.8164	.8997	.9831
13/16	.0677	.1510	.2344	.3177	.4010	.4844	.5677	.6510	.7344	.8177	.9010	.9844
53/64	.0690	.1523	.2357	.3190	.4023	.4857	.5690	.6523	.7357	.8190	.9023	.9857
27/32	.0703	.1536	.2370	.3203	.4036	.4870	.5703	.6536	.7370	.8203	.9036	.9870
55/64	.0716	.1549	.2383	.3216	.4049	.4883	.5716	.6549	.7383	.8216	.9049	.9883
⅞	.0729	.1562	.2396	.3229	.4062	.4896	.5729	.6562	.7396	.8229	.9062	.9896
57/64	.0742	.1576	.2409	.3242	.4076	.4909	.5742	.6576	.7409	.8242	.9076	.9909
29/32	.0755	.1589	.2422	.3255	.4089	.4922	.5755	.6589	.7422	.8255	.9089	.9922
59/64	.0768	.1602	.2435	.3268	.4102	.4935	.5768	.6602	.7435	.8268	.9102	.9935
15/16	.0781	.1615	.2448	.3281	.4115	.4948	.5781	.6615	.7448	.8281	.9115	.9948
61/64	.0794	.1628	.2461	.3294	.4128	.4961	.5794	.6628	.7461	.8294	.9128	.9961
31/32	.0807	.1641	.2474	.3307	.4141	.4974	.5807	.6641	.7474	.8307	.9141	.9974
63/64	.0820	.1654	.2487	.3320	.4154	.4987	.5820	.6654	.7487	.8320	.9154	.9987
1												1.0000

—JONES & LAUGHLIN HAND BOOK.

Decimals of an Inch for each 1-64th.

1/32ds.	1/64ths.	Decimal.	Fract'n	1/32ds.	1/64ths.	Decimal.	Fract'n
	1	.015625			33	.515625	
1	2	.03125		17	34	.53125	
	3	.046875			35	.546875	
2	4	.0625	1–16	18	36	.5625	9–16
	5	.078125			37	.578125	
3	6	.09375		19	38	.59375	
	7	.109375			39	.609375	
4	8	.125	1–8	20	40	.625	5–8
	9	.140625			41	.640625	
5	10	.15625		21	42	.65625	
	11	.171875			43	.671875	
6	12	.1875	3–16	22	44	.6875	11–16
	13	.203125			45	.703125	
7	14	.21875		23	46	.71875	
	15	.234375			47	.734375	
8	16	.25	1–4	24	48	.75	3–4
	17	.265625			49	.765625	
9	18	.28125		25	50	.78125	
	19	.296875			51	.796875	
10	20	.3125	5–16	26	52	.8125	13–16
	21	.328125			53	.828125	
11	22	.34375		27	54	.84375	
	23	.359375			55	.859375	
12	24	.375	3–8	28	56	.875	7–8
	25	.390625			57	.890625	
13	26	.40625		29	58	.90625	
	27	.421875			59	.921875	
14	28	.4375	7–16	30	60	.9375	15–16
	29	.453125			61	.953125	
15	30	.46875		31	62	.96875	
	31	.484375			63	.984375	
16	32	.5	1–2	32	64	1.	1

—JONES & LAUGHLIN HAND BOOK.

The following instructions will refresh the memory as to the use of a table of logarithms:

The log. of 2500 is 3.3979	The log. of 2.5 is 0.3979
The log. of 250 is 2.3979	The log. of .25 is —1.3979
The log. of 25 is 1.3979	The log. of .025 is —2.3979

The log. of 2587 is found as follows: Take from the table the log. for 2580, which is 3.4116. The tabular difference in the column on the right is 17. Subtract 2580 from 2587 and multiply the difference, 7, by the tabular difference, 17, and add the result 119 to log. 3.4116, which gives log. 3.41279 as log. of 2587. To insure that the product of the differences is correctly added compare this final log. with the next highest, 2590, in the table and, as it is 3.4133, the result found is correct.

Conversely given, log. 3.41279 to find the number. An inspection of the table shows that this log. is not in it, so we take the next lowest, which is 3.4116, corresponding to the number 2580. The difference between these two logs. is 119, which, divided by the tabular difference, 17, gives 7 as the figure to be added to 2580 in order to get the exact number corresponding to log. 3.41279.

To multiply numbers add their logarithms and find from the table the number corresponding to the new logarithm thus found.

To divide one number by another find the difference between their logarithms and the new logarithm thus found is the logarithm of the quotient.

To perform an example in proportion add the logarithms of the two numbers that are to be multiplied together and subtract from this new logarithm the logarithm of the divisor, the number corresponding to the final log. being the result wanted.

To raise a number to any power multiply by the exponent of that power. That is, to square a number multiply its log. by two and the number corresponding to the new log. is the square of the first number. This applies to all powers.

To extract the root of any number divide its log. by the index of the root and the number corresponding to the new log. is the required root of the number. This is true for all roots.

No formula containing a plus or minus sign can be solved directly by logarithms; for adding logarithms is equivalent to multiplying their numbers and subtracting logarithms is equivalent to performing the operation of division with their numbers.

LOGARITHMS OF NUMBERS.

No.	0	1	2	3	4	5	6	7	8	9	Diff.
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	40
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	37
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	33
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	31
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	29
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	27
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	25
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	24
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	23
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	21
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	21
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	20
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	19
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	18
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	17
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	17
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	16
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	16
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	15
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	14
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	14
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	13
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	13
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	13
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	13
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	12
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	12
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	12
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	12
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	11
No.	0	1	2	3	4	5	6	7	8	9	Diff.

—JONES & LAUGHLIN HAND BOOK.

LOGARITHMS OF NUMBERS—Continued.

No.	0	1	2	3	4	5	6	7	8	9	Diff.
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	11
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	10
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	10
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	10
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	10
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6818	10
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	9
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	9
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	9
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	9
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	9
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	8
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	8
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	8
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	8
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	8
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	8
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	8
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	7
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	7
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	7
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	7
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	7
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8819	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	6
No.	0	1	2	3	4	5	6	7	8	9	Diff.

—JONES & LAUGHLIN HAND BOOK.

LOGARITHMS OF NUMBERS—Continued.

No.	0	1	2	3	4	5	6	7	8	9	Diff.
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	7
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	6
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	6
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	6
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	6
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	6
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	6
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	6
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	6
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	6
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	5
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	5
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	5
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	5
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	5
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	5
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	4
No.	0	1	2	3	4	5	6	7	8	9	Diff.

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SINKING FUNDS.

In an earlier chapter a table has been given dealing with sinking funds. It was stated there that in the case of a payment of a premium on the bonds the tables did not suffice.

If the amount to be repaid is 104%, then the equivalent depreciation is 2% ÷ 1.04 = 1.9231, and to get this we must go to the formula from which the table was computed.

n = number of years, term of amortization.

r = rate of interest received.

x = rate of depreciation charge, or annual sinking fund installments in dollars per dollar.

$$n = \frac{\log \frac{r + x}{x}}{\log (1 + r)}$$

we obtain

$$n = \frac{\log. \frac{.05 + .019231}{.019231}}{\log .1.05}$$

$$= \frac{\log\ 3.60}{\log\ 1.05} = \frac{0\ 55630}{0.02119} = 26.25 \text{ years.}$$

The formula for rate of depreciation charge is

$$x = \frac{r}{(1 + r)^n - 1}$$

The preceding formulas and the tables referred to in an earlier chapter are for interest compounded yearly. The following formula is for calculating sinking funds with interest compounded half yearly.

A is the annual installment. The first payable one year after investment and the last one at the end of n years.

C is total capital invested.

r is one dollar plus six months' interest.

n is the number of years from investment to the maturity of the sinking fund, when the latter will become equal to the capital originally invested.

$$\frac{A}{C} = \frac{r^2 - 1}{r^{2n} - 1}$$

SHEET IRON AND STEEL.

WEIGHT OF SUPERFICIAL FOOT, BIRMINGHAM GAUGE.

Gauge.	Weight in Lbs.		Gauge.	Weight in Lbs	
	Iron.	Steel.		Iron.	Steel.
No. 1=.3	12.12	12.36	No. 16=.065	2.63	2.68
" 2=.284	11.48	11.71	" 17=.058	2.34	2.39
" 3=.259	10.47	10.68	" 18=.049	1.98	2.02
" 4=.238	9.62	9.81	" 19=.042	1.70	1.73
" 5=.22	8.89	9.07	" 20=.035	1.56	1.59
" 6=.203	8.20	8.36	" 21=.032	1.40	1.43
" 7=.18	7.27	7.42	" 22=.028	1.25	1.28
" 8=.165	6.67	6.80	" 23=.025	1.12	1.14
" 9=.148	5.98	6.10	" 24=.022	1.	1.02
" 10=.134	5.42	5.53	" 25=.02	.9	.92
" 11=.12	4.85	4.95	" 26=.018	.8	.82
" 12=.109	4.41	4.50	" 27=.016	.72	.73
" 13=.095	3.84	3.92	" 28=.014	.64	.65
" 14=.083	3.35	3.42	" 29=.013	.56	.57
" 15=.072	2.91	2.97	" 30=.012	.5	.51

TANK IRON AND STEEL.

WEIGHT OF SUPERFICIAL FOOT.

Thickness in Inches.	Weight in Lbs.		Thickness in Inches.	Weight in Lbs.	
	Iron.	Steel.		Iron.	Steel.
$\frac{1}{32}$=.03125	1.27	1.30	$\frac{5}{16}$= .3125	12.63	12.88
$\frac{1}{16}$=.0625	2.52	2.57	$\frac{3}{8}$= .375	15.16	15.46
$\frac{3}{32}$=.09375	3.79	3.87	$\frac{7}{16}$= .4375	17.68	18.03
$\frac{1}{8}$=.125	5.05	5.15	$\frac{1}{2}$= .5	20.21	20.61
$\frac{5}{32}$=.15625	6.32	6.45	$\frac{9}{16}$= .5625	22.73	23.19
$\frac{3}{16}$=.1875	7.58	7.73	$\frac{5}{8}$= .625	25.26	25.77
$\frac{7}{32}$=.21875	8.84	9.02	$\frac{3}{4}$= .75	30.31	30.92
$\frac{1}{4}$=.25	10.10	10.30	$\frac{7}{8}$= .875	35.37	36.08
$\frac{9}{32}$=.28128	11.38	11.61	1 =1.	40.42	41.23

The low temperature (as compared with Iron) at which Steel Plates have to be finished, causes a slight springing of the rolls, leaving the plate thicker in the center. This, combined with greater density, causes Steel Plates, if kept up to full thickness on the edges, to weigh more than Iron. Both Iron and Steel over 72 inches wide are liable to run even heavier than the weights given above.

WEIGHT OF BAR STEEL PER LINEAL FOOT.

Width in Inches.	Thickness in Inches: 1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1
1	.21	.43	.638	.850	1.06	1.28	1.49	1.70	2.12	2.55	2.98	
1 1/8	.24	.48	.720	.935	1.20	1.43	1.68	1.92	2.39	2.87	3.35	3.83
1 1/4	.27	.53	.797	1.06	1.33	1.59	1.86	2.12	2.65	3.19	3.72	4.25
1 3/8	.30	.59	.875	1.17	1.46	1.76	2.05	2.34	2.92	3.51	4.00	4.68
1 1/2	.32	.64	.957	1.28	1.59	1.92	2.23	2.55	3.19	3.83	4.47	5.10
1 5/8	.35	.69	1.04	1.38	1.73	2.08	2.42	2.77	3.46	4.15	4.84	5.53
1 3/4	.38	.75	1.11	1.49	1.86	2.23	2.60	2.98	3.72	4.47	5.20	5.95
2	.43	.85	1.28	1.70	2.12	2.55	2.98	3.40	4.25	5.10	5.95	6.80
2 1/4	.48	.96	1.44	1.91	2.39	2.87	3.35	3.83	4.78	5.75	6.69	7.65
2 1/2	.53	1.06	1.59	2.12	2.65	3.19	3.72	4.25	5.31	6.38	7.44	8.50
2 3/4	.59	1.17	1.75	2.34	2.92	3.51	4.09	4.67	5.84	7.02	8.18	9.35
3	.64	1.28	1.91	2.55	3.19	3.83	4.46	5.10	6.38	7.65	8.93	10.20
3 1/4	.69	1.38	2.07	2.76	3.45	4.15	4.83	5.53	6.91	8.29	9.67	11.05
3 1/2	.75	1.49	2.23	2.98	3.72	4.47	5.20	5.95	7.44	8.93	10.41	11.90
3 3/4	.80	1.60	2.39	3.19	3.99	4.78	5.58	6.38	7.97	9.57	11.16	12.75
4	.85	1.70	2.55	3.40	4.25	5.10	5.95	6.80	8.50	10.20	11.90	13.60
4 1/2	.96	1.92	2.87	3.83	4.78	5.74	6.70	7.65	9.57	11.48	13.39	15.30
5	1.07	2.13	3.19	4.25	5.31	6.38	7.44	8.50	10.63	12.75	14.87	17.00
5 1/2	1.17	2.34	3.51	4.67	5.84	7.02	8.18	9.35	11.69	14.03	16.36	18.70
6	1.28	2.55	3.83	5.10	6.38	7.65	8.93	10.20	12.75	15.30	17.85	20.40
7	1.49	2.98	4.46	5.95	7.44	8.93	10.41	11.90	14.87	17.85	20.83	23.80
8	1.70	3.40	5.10	6.80	8.50	10.20	11.90	13.60	17.00	20.40	23.80	27.20

Size in Inches.	Rounds, Weight in Lbs.	Squares, Weight in Lbs.	Size in Inches.	Rounds, Weight in Lbs.	Squares, Weight in Lbs.
3/16	.094	.120	2 1/8	12.06	15.36
1/4	.167	.213	2 1/4	13.52	17.22
5/16	.261	.332	2 3/8	15.07	19.19
3/8	.375	.478	2 1/2	16.70	21.26
7/16	.511	.651	2 5/8	18.41	23.44
1/2	.668	.851	2 3/4	20.21	25.73
9/16	.845	1.076	3	24.05	30.62
5/8	1.044	1.329	3 1/4	28.23	35.94
3/4	1.503	1.914	3 1/2	32.74	41.68
7/8	2.046	2.605	3 3/4	37.57	47.84
1	2.672	3.402	4	42.77	54.45
1 1/8	3.382	4.306	4 1/2	54.83	69.81
1 1/4	4.175	5.316	5	66.82	85.08
1 3/8	5.052	6.432	5 1/2	80.85	102.94
1 1/2	6.012	7.655	6	96.22	122.51
1 5/8	7.056	8.984	6 1/2	112.92	143.78
1 3/4	8.183	10.419	7	130.97	166.75
1 7/8	9.394	11.961	7 1/2	150.34	191.42
2	10.69	13.61	8	171.04	217.78

Weights and Areas of Square and Round Steel, also Circumference of Round Bars.

Assuming one cubic foot to weigh 490 lbs.

Thickness or Diameter in Inches.	Weight of Square Bar 1 ft. long.	Weight of Round Bar 1 ft. long.	Area of Square Bar in Square Inches.	Area of Round Bar in Square Inches.	Circumference of Round Bar in Inches.
3/16	.120	.094	.0352	.0276	.5890
1/4	.213	.167	.0625	.0491	.7854
5/16	.332	.261	.0977	.0767	.9817
3/8	.478	.375	.1406	.1104	1.1781
7/16	.651	.511	.1914	.1503	1.3744
1/2	.851	.668	.2500	.1963	1.5708
9/16	1.076	.845	.3164	.2485	1.7671
5/8	1.329	1.044	.3906	.3068	1.9635
11/16	1.608	1.263	.4727	.3712	2.1598
3/4	1.914	1.503	.5625	.4418	2.3562
13/16	2.246	1.764	.6602	.5185	2.5525
7/8	2.605	2.046	.7656	.6013	2.7489
15/16	2.990	2.348	.8789	.6903	2.9452
1	3.402	2.672	1.0000	.7854	3.1416
1/16	3.841	3.017	1.1289	.8866	3.3379
1/8	4.306	3.382	1.2656	.9940	3.5343
3/16	4.798	3.768	1.4102	1.1075	3.7306
1/4	5.316	4.175	1.5625	1.2272	3.9270
5/16	5.861	4.603	1.7227	1.3530	4.1233
3/8	6.432	5.052	1.8906	1.4849	4.3197
7/16	7.030	5.521	2.0664	1.6230	4.5160
1/2	7.655	6.012	2.2500	1.7671	4.7124
9/16	8.306	6.524	2.4414	1.9175	4.9087
5/8	8.984	7.056	2.6406	2.0739	5.1051
11/16	9.688	7.609	2.8477	2.2365	5.3014
3/4	10.419	8.183	3.0625	2.4053	5.4978
13/16	11.177	8.778	3.2852	2.5802	5.6941
7/8	11.961	9.394	3.5156	2.7612	5.8905
15/16	12.772	10.031	3.7539	2.9483	6.0868

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WEIGHT OF A CUBIC FOOT OF SUBSTANCES.

Names of Substances.	Average Weight, lbs.
Aluminum, cast	160
" rolled	167
Anthracite, solid, of Pennsylvania	93
" broken, loose	54
" " moderately shaken	58
" heaped, bushel, loose	(80)
Ash, American white, dry	38
Asphaltum	87
Brass (Copper and Zinc), cast	504
" rolled	524
Brick, best pressed	150
" common hard	125
" soft, inferior	100
Brickwork, pressed brick	140
" ordinary	112
Cement, hydr'c, ground, loose, American, Rosendale	56
" " " " " Louisville	50
" " " " English, Portland	90
Cherry, dry	42
Chestnut, dry	41
Clay, potters', dry	119
" in lump, loose	63
Coal, bituminous, solid	84
" " broken, loose	49
" " heaped, bushel, loose	(74)
Coke, loose, of good coal	26
" " heaped bushel	(40)
Copper, cast	549
" rolled	556
Earth, common loam, dry, loose	76
" " " " moderately rammed	95
" as a soft flowing mud	108
Ebony, dry	76
Elm, dry	35
Flint	162
Glass, common window	157
Gneiss, common	168

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WEIGHT OF SUBSTANCES—Continued.

Names of Substances.	Average Weight, lbs.
Gold, cast, pure, or 24 carat	1204
" pure, hammered	1217
Grain, at 60 lbs. per bushel	48
Granite	170
Gravel, about the same as sand, which see.	
Gypsum (plaster of paris)	142
Hemlock, dry	25
Hickory, dry	53
Hornblende, black	203
Ice	58.7
Iron, cast	450
" wrought, purest	485
" " average	480
" ore	175
Ivory	114
Lead	711
Lignum-vitæ, dry	83
Lime, quick, ground, loose, or in small lumps	53
" " " " thoroughly shaken	75
" " " " per struck bushel	(66)
Limestones and Marbles	168
" " loose, in irregular fragments	96
Magnesium	109
Mahogany, Spanish, dry	53
" Honduras, dry	35
Maple, dry	49
Marbles, see Limestones.	
Masonry, of granite or limestone, well-dressed	165
" " mortar rubble	154
" " dry " (well scabbled)	138
" " sandstone, well dressed	144
Mercury, 32° Fahrenheit	849
Mica	183
Mortar, hardened	103
Mud, dry, close	80 to 110
" wet, fluid, maximum	120
Oak, live, dry	59

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WEIGHT OF SUBSTANCES—Continued.

Names of Substances.	Average Weight, lbs.
Oak white, dry	50
" other kinds	32 to 45
Petroleum	55
Pine, white, dry	25
" yellow, Northern	34
" " Southern	45
Platinum	1342
Quartz, common, pure	165
Rosin	69
Salt, coarse, Syracuse, N. Y.	45
" Liverpool, fine, for table use	49
Sand, of pure quartz, dry loose	90 to 106
" well shaken	99 to 117
" perfectly wet	120 to 140
Sandstones, fit for building	151
Shales, red or black	162
Silver	655
Slate	175
Snow, freshly fallen	5 to 12
" moistened and compacted by rain	15 to 50
Spruce, dry	25
Steel	490
Sulphur	125
Sycamore, dry	37
Tar	62
Tin, cast	459
Turf or Peat, dry, unpressed	20 to 30
Walnut, black, dry	38
Water, pure rain or distilled, at 60° Fahrenheit	62½
" sea	64
Wax, bees	60.5
Zinc or Spelter	437.5

Green timbers usually weigh from one-fifth to one-half more than dry.

—JONES & LAUGHLIN HAND BOOK.

BEAM CALCULATIONS.

The town engineer is called upon to design many structures of a simple kind and a discussion of the underlying principles of beam formulas will be a useful review. After this we will take up the design of walls, culverts, etc.

MOMENTS.

When a weight rests upon an object it strains it in some degree. If the object is lying on the ground supported throughout its entire length, the force is simply equal to the weight.

When the object is a beam, for example, supported at the ends, the weight acts in two ways. First, it tends to shear the beam at each point of support and, secondly, it tends to bend the beam. The force exerted in bending is called a moment.

The moment of a force is the product of the force into the arm with which it acts. Take, for example, a small piece of wood about one inch square, perfectly level, but with one end fastened into a wall. The other end being free and unsupported. Cut a groove in the top and roll a ball in the groove. The nearer the ball approaches the free end the more the piece of wood bends. If this piece of wood were larger, so that it could be termed a beam, it would be called a cantilever beam. (See Fig. 6.)

If the load is in pounds and the distance from the wall to the load is in feet, the distance multiplied by the weight gives the bending moment in foot pounds. The distance may be (and generally is) taken in inches and the bending moment is given as so many inch-pounds. With the above example the statement that the moment of a force is the product of the force into the arm with which it acts, may be plainly understood. In other words, the farther the load is placed from the point of support, the greater bending moment it develops. The arm is always perpendicular to the direction of the force.

The accompanying diagrams, showing the usual cases occurring in the loading of beams, will help illustrate the definition of bending moments.

The weight does not act directly to cause bending. It must act

through the arm or distance it (the weight) is away from the point where the bending moment is developed. In calculating the strains on beams, the maximum bending moment is the one used.

Weight tends to carry the beam down vertically or in the line of direction in which the weight acts. This action is resisted by the supports under the beam. As soon as resistance is encountered the beam may shear at the edges of the support; that is, be cut off like slicing butter with a knife, or it may bend at some point between the supports. The point may be where the load strikes or it may be somewhere else on the beam. Where the point may be depends upon several things.

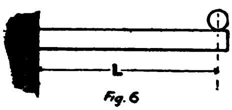


Fig. 6

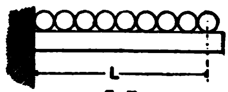


Fig. 7

Fig. 6 illustrates the cantilever beam fastened at one end and loaded with a concentrated weight.

It must be remembered that we can only use the concentrated weight alone in preliminary calculations or in explaining the action of forces. The weight of the beam can not be neglected in practice, so when using a concentrated weight we have of necessity a concentrated as well as a distributed load. This refinement, however, will be neglected in the following discussion for the sake of clearness.

Let W represent a concentrated weight.

L represents the distance between supports.

w represents a distributed weight.

w′ represents the weight of the beam, also distributed.

In Fig. 6 the bending moment is $M = W \times L$.

The maximum bending moment is at the wall. It becomes less the nearer the weight the moment is taken. In the general discussion while the letter L is termed the distance between supports, in the case of the cantilever it is the distance from the support to the center of gravity of the weight.

Fig. 7 shows a cantilever beam with a distributed weight, or load.

A force or weight may be represented by a line, to any scale. The length of the line represents the amount and the direction in

which the force acts is shown by the direction of the line. Usually an arrow point is placed on the line to indicate direction. In the case of weights and the loading of beams it is understood the force acts downward, so the line is vertical.

In Fig. 6 calculate the bending moment. At the support draw a vertical line from the middle of the beam. This line can go up or down, but it is customary to draw it down, as the force acts in that direction. The length of the line will represent the bending moment. Connect the end of it to the center of the beam at a point directly under the center of gravity of the weight. This gives a triangle in which the bending moment at any point in the beam can be found by measuring the perpendicular distance from the center of the beam (base of the triangle) to the limiting line of the force diagram (the hypothenuse of the triangle).

Apply this to Fig. 7. Here the total weight is multiplied by the distance from the support to the center of gravity of the load. That is, by half the length of the load. It is expressed thus:

$$M = w \times \frac{L}{2}$$

The maximum bending moment in this case is also at the point of support. A drawing can be made as in the case of Fig. 6, but the limiting line for a distributed load is a parabola instead of the hypothenuse of a triangle, and it begins at the extreme end of the load. This will be taken up when describing Fig. 15.

There may be cases in which a cantilever beam has to carry its own weight (w′), a distributed load (w), and a concentrated load (W) as well. The bending moment, M, is equal to w′ × L, plus w × L, plus W × L. Each is calculated separately and the results added.

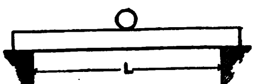


Fig. 8

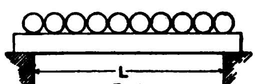


Fig. 9

Fig. 8 is a beam freely supported at both ends with a concentrated load in the middle.

We know by intuition that each support must carry half the load, so the maximum bending moment must be equal to half the load into half the span. That is, the expression is

$$M = W \times \frac{L}{4}$$

which is the same thing. We have calculated the moment for two cantilevers, but in this case the beam has two end supports, so the maximum bending moment must be in the middle under the load.

Fig. 9 shows a distributed load on a beam freely supported at both ends. We have already seen that the maximum bending moment for a distributed load is one-half that of the same load concentrated, so the expression in this case is

$$M = w \times \frac{L}{8}$$

A distributed load has a tendency to arch. It is illustrated in the case of a brick wall. When calculating the load borne by the top of a window or door frame, the weight is not that included between the vertical lines from the sides of the opening to the top of the structure. It is the weight of a triangle of wall having the three sides equal to the span of the opening. The bricks have a tendency to key together, aside from the adhesion caused by the mortar.

Similarly with a distributed load of boxes, or bags, or rails. The question also arises in computing the pressure on the top of a culvert under a high fill. As the beam gives way the pieces composing the load adjust themselves until they form practically a beam and can be self-supporting over a considerable span. Tests of beams loaded with materials piled haphazard on them are not reliable. The load should be piled in slender columns with well defined spaces between, so that when the beam bends the material can not heap and relieve the loading.

In order to express this clearly and lead to a ready understanding of Fig. 15, distributed loads in this discussion have been represented by lines of balls free to move and adjust themselves to the changing form of the beam as it bends.

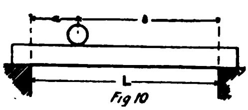


Fig 10

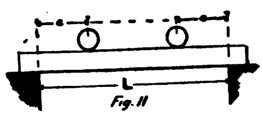


Fig. 11

Fig. 10 differs from Fig. 8 in that the concentrated load is not in the middle. Calling half the length a, it can be proven that

$$M = \frac{W}{2} \times \frac{L}{2} = W \times \frac{L}{4} = W \times \frac{a^2}{L}$$

as shown in the case illustrated by Fig. 8.

A similar line of reasoning for Fig. 10 gives the following expression:

$$M = W \times \frac{a \times b}{L}$$

for a concentrated load not at the middle.

Fig. 11 shows a beam having two equal concentrated loads, equally distant from the center. In this case

$$M = W \times a$$

No particular illustration is needed in this case, as a careful following of the preceding explanations will show how the formula is developed. However, the explanation of Fig. 14 will help throw light on it.

Fig. 12 shows a combination wherein the concentrated load is distributed over a portion of the beam. Where a and b are equal, the formula is

$$M = \frac{W \times L}{4} - \frac{W \times l}{8}$$

When the distances from the points of support to the center of gravity of the load are not equal the expression is

$$M = \frac{W \times a \times b}{L} - \frac{W \times l}{8}$$

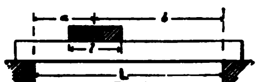


Fig. 12

IRREGULAR LOADINGS.

After discussing reactions we will take up the calculation of

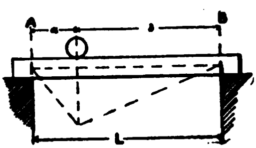


Fig. 13

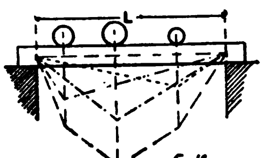
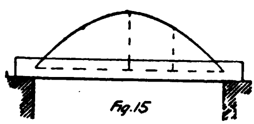


Fig. 14

the location of the maximum bending moment under irregular loadings. The position, however, may be determined graphically.

Fig. 13 illustrates the method of drawing triangles already described. The bending moment is calculated and represented by a line drawn vertically downward from the center of gravity of the load. The triangle is completed by drawing the hypothenuse. The bending moment at any intermediate point is found by measuring vertically downward from the middle of the beam at the point, to the hypothenuse.

When there are several loads the bending moment is calculated for each and a triangle plotted for each, as shown in Fig. 14. It will be noticed that under each loal several triangles cross. The bending moment under each load is therefore equal to the sum of the distances from the center of the beam to the hypothenuse of each triangle. Connect the outside points thus found and draw in the exterior line. A perpendicular dropped to the outside diagram from any point gives the bending moment at that point. The maximum bending moment is at the point where the longest vertical line can be drawn from the center of the beam to the outside force diagram.



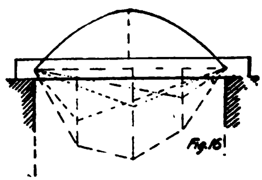


Fig. 15 shows the force diagram of a distributed load. The maximum bending moment $\left(M = \frac{W \times l}{8}\right)$, is set off at the point half way between the supports. A parabola is then drawn with a height equal to this bending moment and a base equal to the distance or clear span. All measurements are made on a horizontal line through the middle of the beam.

The reason for the parabola may be seen by a reference to Fig. 9 and Fig. 14. The distributed load can be represented by a line of balls and the force triangles plotted for each. These triangles of force can be worked into a force diagram which will assume the shape of a parabola. Having ascertained this, it is unnecessary to again go through this process and the parabola may be drawn directly when it is desired that the bending moment on a beam

uniformly loaded is required to be known at any other point than the middle.

Fig. 16 hardly needs a detailed description. It shows how to ascertain the maximum and other bending moments in a beam loaded with a distributed and any number of concentrated loads. The maximum bending moment is at the point where the longest vertical line can be drawn between the parabola and the bounding lines of the other force diagram. The location can be calculated also if the graphical process is not used.

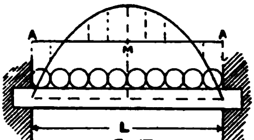


Fig. 17

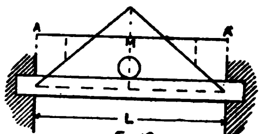


Fig 18

In the preceding explanations all beams have been considered as simply resting upon the supports. Fig. 17 shows a beam loaded with a distributed load and having the ends fastened into the wall.

By calculations which would hardly be interesting in this review, it can be proven that for such a case the maximum bending moment is $M = w \times \frac{L}{12}$ instead of $M = w \times \frac{L}{8}$ as in the case already mentioned. The diagram in Fig. 17 is constructed by drawing a parabola having $M = w \times \frac{L}{8}$. Also A, A′ parallel to base and at a distance equal to $M = w \times \frac{L}{12}$. The vertical distances between the parabola and the line A A′ are the moments for the corresponding points on the beam.

In such beams there are points known as points of contra flexure. That is, instead of the beam bending in the middle and the ends raising slightly, the ends remain fixed and the beam bends in three points. At the middle it is concave on the top and on the bottom are two points distant 0.21131 of the span from each support, where the beam bends downward, or is concave on the bottom.

Fig. 18 shows a tied beam having a load concentrated at the middle. This diagram is drawn by drawing a triangle having

$M = W \times \frac{L}{4}$. Also A A′ parallel to the base and at a distance of $M = W \times \frac{L}{8}$ The vertical distances between the triangle and the line A A′ are the moments for the corresponding points on the beam.

The points of contraflexure are ¼ L from the points of support. In the case of Fig. 17 the maximum bending moment was for a distributed load. In the case of Fig. 18 we use a concentrated load, giving $M = W \times \frac{L}{4}$ plus the distributed load equal to the weight of the beam; thus, $M = w' \times \frac{L}{8}$

It is important to remember the weight of the beam *in all* calculations. This weight is called the dead load. The superimposed weight is called the live load. In a structure the weight of the structure is the dead load and the weights the structure is designed to carry constitute the live load.

The method of finding the maximum bending moment for a beam carrying a distributed load together with a concentrated load has been given. Also the method of finding the maximum bending moment caused by several concentrated loads. The most simple way of obtaining the moment in such cases is to reduce each concentrated load to a distributed load and add these distributed loads together and calculate the maximum bending moment for the total equivalent distributed load, an easy matter.

A distributed load gives a moment one-half that given by an equal concentrated load applied at the middle of the span. So for a concentrated load at middle of the span multiply by 2. At 0.333 of the span from a support, multiply by 1.78. At 0.25 the span. by 1.5. At 0.20 the span, by 1.28. At 0.166 the span, by 1.111. At 0.143 the span, by 0.98. At 0.125 the span, by 0.875. At 0.111 the span, by 0.79. At 0.10 the span, by 0.72.

The foregoing method is used in many offices and is a labor saver. A caution, however, must be given to users, that, as the maximum bending moment is not exactly equal to the sum of the separate bending moments, a beam calculated by this method will be larger than would be required if the more exact process were

followed. This caution is necessary however, only when the weights are very heavy.

CONTINUOUS BEAMS.

The foregoing cases touch upon beams resting on two supports and also the case of beams tied at each end. Continuous beams are beams that rest on more than two supports; for example, a beam across from wall to wall in a building and resting upon a post in the middle. It is then a continuous beam of two spans. If it had rested upon two intermediate posts it would be a continuous beam of three spans.

Each span assists the adjoining span in nearly all cases, and there are points of contra-flexure in each span.

A continuous beam of two spans uniformly loaded is no stronger than a beam of one span so loaded.

A continuous beam of two spans loaded with a concentrated load at the center of each span is stronger than a simple beam. The bending moment in each span is one-fourth less than if the beam were not continuous.

When the beam is continuous over three spans and the load is uniformly distributed, the bending moment in each span is eight-tenths the load on a single span for a non-continuous beam.

The bending moment on each span of a three-span continuous beam having concentrated loads of equal weight in the middle of each span is six-tenths the bending moment on a simple span.

The foregoing remarks apply only to beams having two and three spans of equal length with equal loads on each span.

REACTIONS.

The loads on a beam tend to carry it downward. The supports prevent this action. The effort put forth by the supports is termed a reaction. It is said that the supports push up with a force equal to that exerted downward by the load.

In Fig. 6 and Fig. 7 the reaction at the point of support is equal to the combined weights of the beam and the load.

In Fig. 9 the reaction at each support is equal to one-half the total weight.

In Fig. 13 the reaction at B is equal to the moment produced by the load multiplied by the distance a, divided by the span. The reaction at A is equal to the reaction at B subtracted from the

total load. The above operation can be reversed for a check. The reaction therefore at any support is equal to the load multiplied by its distance from the other support and divided by the span. The reaction at the opposite support is the difference between the total load and the reaction first found.

In the case of several loads, as in Fig. 14, find the moment for each about the opposite support and add together all these moments. Divide by the length of the span and the reaction is obtained. To obtain the other reaction, add the loads together and subtract the first reaction from the sum.

In dealing with concentrated loads in finding reactions, half the weight of the beam is afterward added to each reaction. The weight of the beam can therefore be neglected in the calculations, provided it is afterward added.

If a beam projects from a wall and rests on a post or end of a brace, like a balcony, for example, there will be two reactions. At the wall where the beam is fastened the reaction will be downward and at the support it will be upward, provided, of course, the load is outside the post. If between the post and wall the reactions are figured in the manner already described. Multiply the load by the total distance from its center of gravity to the wall and divide by the distance from the wall to the post. This gives the reaction at the post and this is plus, or acting upward. Subtract this from the load to get the minus, or downward reaction at the wall, or tied end.

In the case of a load, as shown in Fig. 12, it is enough to simply take the weight of the whole object to be a concentrated load applied at its center of gravity and calculate accordingly. The length then of the load makes no particular difference.

It is because of the reactions there are bending moments and shearing strains in beams, so we have to find the bending moments in order to find the reactions.

SHEARING FORCE.

If a beam is made of a tough material it will bend, as has been shown, whenever the ends rest on supports and the span between is free. If the material were soft it would cut in two at the supports, because of its weight and the weight of the load. This action is termed shear. It exists in a greater or less degree in each point in the length of the beam.

In Fig. 6 the shear is equal to the total load and is the same at every point. The shear diagram is a parallelogram.

In Fig. 7 the maximum shear is at the fixed end and is equal to the weight per lineal foot multiplied by the length. The shear at any point is equal to the weight per lineal foot into the distance to that point. The shear diagram is a triangle.

In all beams the maximum shear is at one of the supports. When beams rest freely at both ends the shear is equal to the greater reaction or supporting force.

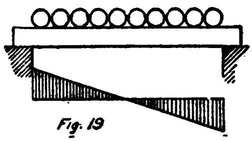


Fig. 19

In Figs. 19 and 20 the shear is equal to one-half the total load.

In the shear diagrams the shaded parts represent the amount of shear and the following rules explain how the shear diagram is obtained.

Calling the loads, the forces acting downward, plus, the reactions, forces acting upward are called minus. Beginning with either reaction, put it down with its sign. Add to it, algebraically, the first load. This gives the shear for every point from the origin to that point. Add to this, algebraically, the next load and continue in this manner until the end of the beam is reached. At some point on the beam the shears become positive if they were first negative, or vice versa.

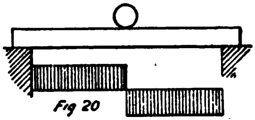


Fig 20

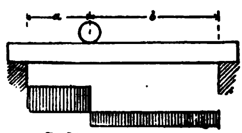


Fig 21

A study of Figs. 21, 22 and 23 should make this plain. In Fig. 21 the maximum shear $= W \times \frac{b}{L.}$ In Fig. 22 the loads are equal and at equal distances from the ends. The maximum shear is therefore equal to the total load.

Reference has been made to the calculation of the position of

maximum bending moment. The points of maximum bending moment occur where the shear changes sign.

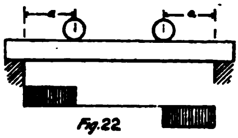


Fig. 22

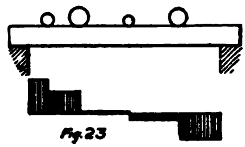


Fig. 23

A general rule for finding the bending moment at any point of any beam is to add together the bending moment at the origin, the sum of the moments of all concentrated loads to that point, including the shear at the origin, and the sum of the moments of the distributed loads about the same point. This rule can be checked by constructing a force diagram and measuring the bending moments at several points and then calculating them.

When a beam is uniformly loaded and in addition carries a single concentrated load the position of the maximum bending moment is found by dividing the moment of the concentrated load by the distributed load. This may give a plus or a minus result, which will indicate the distance to the right or left of the middle of the beam of the position of maximum bending moment caused by the combination of the loads. It is a good plan to consider the origin as being at the left in calculating the moment for the concentrated load.

APPLICATIONS.

A knowledge of the actions of forces in beams is useful in designing buildings, culverts, bins, retaining walls, etc., and as the engineer should be well posted in bridge work before designing anything larger than a fifteen or twenty-foot span bridge, we need not touch upon the subject of moving loads.

It will be sufficient to take the length of the heaviest engine or wagon that will cross the bridge. Find the weight and distribute it over the four wheels. Consider the two wheels on one side as concentrated loads and calculate the maximum bending moment for these loads in different positions on the beam. Design the beam for the greatest moment found. The total live load is generally distributed in calculations.

The expression, wl^2, is often met. It simply means that w is

the unit load, the load per foot or per inch. To get the total load it is necessary to multiply the unit load by the length. Then in cases where the total load has to be multiplied by the length it really amounts to the unit load being twice multiplied by l, or, rather, by l^2.

We have seen that for a beam freely supported at both ends a distributed load causes a bending moment, $M = \frac{wl^2}{8}$, and when the ends are fastened, $M = \frac{wl^2}{12}$. In reinforced concrete floors, fastened firmly on four sides, it is allowable to use $M = \frac{wl^2}{20}$.

A floor is a slab composed of beams lying side by side. To calculate the strength of a floor we simply take a strip one foot wide and use the load coming on that portion. A wall is a succession of beams fastened edge to edge. If the beams are calculated as being vertical they are all cantilevers. If they are calculated as being horizontal their thickness depends upon the length of the beam between vertical supports. These supports may be columns or buttresses or ties in the rear. In olden days the ties in the rear were called counterforts but were of little service, for a severe load against the wall tore it from the counterforts.

Today the use of reinforced concrete makes counterforts practical and really useful. A retaining wall may be designed as a vertical slab held in place by counterforts at regular intervals. This will be taken up later.

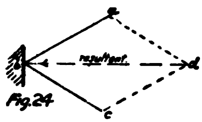
STRAINS IN STRUCTURES.

It has been mentioned that forces may be represented by lines to some scale and the direction in which the forces act may be represented by the direction of the lines. An understanding of these principles has led to the development of Graphic Statics, or the art of calculation by drawing lines.

Fig. 24 is the old familiar diagram of the parallelogram of forces. A B represents in amount and direction a certain force. B C represents in amount and direction another force. They act together at the point B. The line B D is called the resultant. To find it draw a line from A parallel with B C and draw a line to intersect it from C, parallel with A B. The line B D connecting

the opposite corners is the resultant in amount and direction that tends to move the object at the point B.

The same result could be obtained in a neater manner by setting off the line A B from the end C of B C and completing the triangle. Any number of forces can be thus connected, by joining one after another to the lines already drawn, until we have a diagram lacking one side. A line drawn to fill this missing part of the diagram will represent in amount and direction the resultant of all the forces.



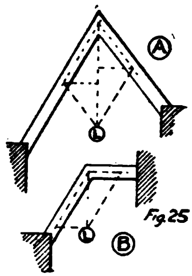


Fig. 25 shows two common arrangements of braces. In each case draw a vertical line from the joint to represent the weight on the frame. From the end of this line draw lines parallel to the pieces of frame work. The lengths of these lines measured on the same scale as that of the vertical line gives the amount of force each piece puts forth to resist the weight. The small horizontal lines in the diagram (A) represent the thrust of the feet of the braces against the abutments. The vertical line represents the total weight. Part is borne by one abutment and part by the other. The sum of these two portions represents the total weight. The portion of the vertical line (measuring downward) intercepted by a horizontal line, represents the part of the weight borne by the brace toward which that horizontal line goes.

Fig. 26 contains several diagrams of interest. In (1) is shown a beam A C having a rope A B C, attached at each end and carrying a load L. To the right draw (2) which contains a vertical line a c representing the amount of the load. The lines a b and b c are drawn, respectively, parallel to A B and B C. They represent the tension in those portions of the rope. From b draw b d

parallel to A C. This shows the compression in the beam A C. Only a portion of the load exerts compression on A C, for the whole load is finally carried by the supports on which the beam rests. The line a d shows the load on the support at A and c d shows the load on the support at C.

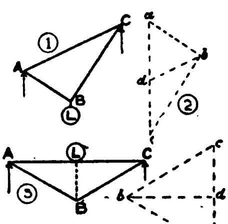


Fig. 26

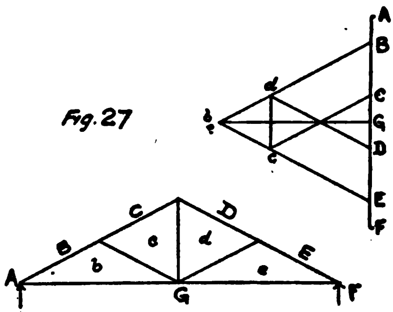


Fig. 27

In (3) is shown a trussed beam A C loaded with a load L. There is a vertical strut B L under the load and from the ends of the beam to the lower end of the strut are ties A B and B C. On the right draw (4) in which a c represents the load drawn to scale. Draw a b from one end, parallel to A B and draw b c from the other end parallel to B C. They will meet in b from which point draw b d parallel to A C, which represents the stress on each half of the beam A. C. The loads on the supports are shown by c d and a d.

The trussed beam shown in (3) of Fig. 26 can be inverted, and instead of a strut L B there can be used a rod. The rods A B and B C can be replaced by rafters and we have a simple roof truss, in which the strains are reversed, being in tension where they were in compression, etc.

Fig. 27 represents a roof truss of a more complicated form. The vertical line from the apex is a tie and the horizontal lines are ties. They are in tension and the inclined pieces are in compression.

The truss is figured as if alone, for no matter how many trusses there may be, when one is calculated the rest are similar, except at the ends, but there the walls will carry the load. The

load on a truss consists of the weight of a strip of roof extending half way on each side to the next truss and from one support to the other. That is a strip the width of the space between trusses and in length equal to the rafter lengths.

Of course all the load, including the weight of the truss, goes into the walls and sets up reactions. But this is neglected in computing strains in the members. The total load is divided into as many parts as there are supporting joints on the rafters, counting the two ends as one. In this roof there are four. One part of the load is supposed to act at each joint and half of one part at each end where the roof rests on the walls. In the calculations this part is not considered.

Draw the vertical line A F. A B represents the load on one wall and E F the load on the other wall so far as the distributed loads go to the joints. The part B C represents the load on the joint between B and C. That between C D the load at the apex etc. From B draw the line B b parallel with the rafter on the left and from E draw the line E e parallel with the rafter on the right. The lengths of these lines represent stresses on the portions of the rafters between the joints and the feet.

From C draw the line C c parallel with the rafter on the left and from D the line D d parallel with the rafter on the right. These lines represent stresses in the upper ends of the rafters.

It will be noticed that the lines are lettered with capital letters and the inside spaces have small letters. In the stress diagram these letters are at points. The line between two points represents the member between corresponding letters on the truss diagram.

Referring again to the diagram, b c represents the stress on the strut on the left between the spaces b and c, and e d represents the stress on the strut on the right between the spaces d and e. The vertical line c d represents the stress on the vertical tie rod. G b the stress on the horizontal tie rod on the left side and G e the stress on the horizontal tie rod on the right side.

As the vertical line A F in the stress diagram represents the total load of the roof so A G is the total reaction at support A and G F the total reaction at the point F.

The stresses are divided into tensile and compressive. In making the stress diagram we commenced at A and went to F, the capital letters denoting panel points. Following the lines in

the same order all stresses acting toward panel points are compressive and those acting away are tensile, the vertical weight line not being considered. From G to e is a tensile stress. From b to A or from e to F compressive. The forces act from A toward the apex so following them in that direction it is easy to determine the nature of the strain in each member.

The method of Graphic Statics is applicable to all forms of trusses, to retaining walls, arches, etc. With the elementary ideas set forth here any man with a little careful thought should be able to construct a diagram of forces for almost all simple forms of trusses. Sondericker's Graphic Statics ($2.00) is an excellent book for further study.

Notice the words "stress" and "strain." Stress is a measure of a force. Strain is the deformation caused in a piece by a stress.

APPROXIMATE LOADS PER SQUARE FOOT FOR ROOFS OF SPANS UNDER 75 FEET INCLUDING WEIGHT OF TRUSS

Roof covered with corrugated sheets, unboarded	8 lbs
Roof covered with corrugated sheets, on boards	11 "
Roof covered with slate, on laths	13 "
Same, on boards 1¼ in thick	16 "
Roof covered with shingles, on laths	10 "
Add to above, if plastered below rafters	10 "
Snow, light, weighs per cubic foot	5 to 12 "

For spans over 75 ft. add 4 lbs. to the above loads per square foot.

It is customary to add 30 lbs. per square foot to the above for snow and wind when separate calculations are not made.

PRESSURE OF WIND ON ROOFS (Unwin)

a = Angle of surface of roof with direction of wind.
F = Force of wind in pounds per square foot.
A = Pressure normal to surface of roof $= F\ \mathrm{Sin.}\ a^{1.84\ \mathrm{Cos.}\ a-1}$.
B = Pressure perpendicular to direction of wind $= F\ \mathrm{Cot.}\ a\ \mathrm{Sin.}\ a^{1.84\ \mathrm{Cos.}\ a}$
C = Pressure parallel to direction of wind $= F\ \mathrm{Sin.}\ a^{1.84\ \mathrm{Cos.}\ a}$.

Angle of roof = a	5°	10°	20°	30°	40°	50°	60°	70°	80°	90°
A = F ×	.125	.24	.45	.66	.83	.95	1.00	1.02	1.01	1.00
B = F ×	.122	.24	.42	.57	.64	.61	.50	.35	.17	.00
C = F ×	.01	.04	.15	.33	.53	.73	.85	.96	.99	1.00

—CARNEGIE HAND BOOK.

ROOF TRUSSES

TABLES FOR FINDING STRESSES IN MEMBERS FOR ROOF TRUSSES OF THE DIFFERENT TYPES AND PITCHES AS GIVEN BELOW AND OF ANY SPAN

RULE—To find the stress in any member, multiply the coefficient given for that member by total dead load carried by truss (=span in feet × distance between trusses in feet × weight per square foot). If the truss is acted upon by wind forces or other unsymmetrical loading, the stresses in the members must be calculated accordingly and combined with the dead load stresses as found below.

Member of Truss	Pitch (Depth to Span)			
	1/3	30°	1/4	1/5
Fig. 1				
Aa	.675	.750	.838	1.010
Bb	.537	.625	.736	.917
Ca	.563	.650	.750	.938
Cc	.375	.433	.500	.625
ab	.208	.217	.224	.232
bc	.188	.217	.250	.313
Fig. 2				
Aa	.750	.833	.930	1.120
Bb	.589	.666	.757	.928
Cc	.568	.666	.783	.995
Da	.625	.721	.833	1.042
Dd	.375	.433	.500	.625
ab	.155	.167	.180	.202
bc	.155	.167	.180	.202
cd	.250	.288	.333	.417
Fig. 3				
Aa	.788	.874	.978	1.178
Bb	.718	.812	.922	1.131
Cc	.649	.750	.866	1.085
Dd	.580	.687	.810	1.038
Ea	.655	.758	.875	1.094
Ef	.562	.650	.750	.938
Ee	.375	.433	.500	.625
ab	.104	.108	.112	.116
bf	.093	.108	.125	.156
fg	.208	.216	.224	.232
gc	.093	.108	.125	.156
cd	.104	.108	.112	.116
ge	.187	.217	.250	.313
de	.280	.325	.375	.469

NOTE—Heavy lines denote compression and light lines tension members. Loads are considered as concentrated at the joints.

FIG. 1

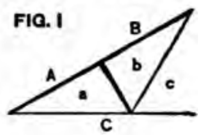


FIG. 2

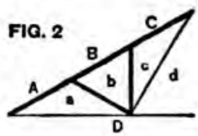
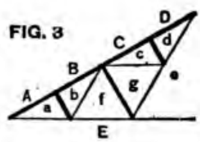


FIG. 3



—CARNEGIE HAND BOOK.

NOTES ON ROOFS AND LOADS FOR SAME

ANGLES OF ROOFS AS COMMONLY USED

Proportion of Rise to Span	Angle		Length of Rafter to Rise	Proportion of Rise to Span	Angle		Length of Rafter to Rise
	Deg.	Min.			Deg.	Min.	
½	45	..	1.4142	¼	26	34	2.2361
⅓	33	41	1.8028	⅕	21	48	2.6926
$\frac{1}{2\sqrt{3}}$	30	..	2.0000	⅙	18	26	3.1623

—CARNEGIE HAND BOOK.

RESISTANCE OF BEAMS.

CENTER OF GRAVITY.

The last section simply mentioned how to calculate the manner in which forces acted and their amounts. Before the question of resistance to the forces can be taken up a few definitions must be given of factors used.

When a piece is acted upon as a whole the resultant of the forces must pass through the center of gravity of the piece. This is the point in which the whole mass of the body might be concentrated, without affecting the force of gravity existing between the piece (or body), no attention being paid to the relative positions or distances of the body and other adjacent bodies.

Parallel forces, (that is, forces acting in the same line) opposite in direction, balance at the center of gravity. A weight acting downward is met by a resultant at the center of gravity and the body is stationary. If the points of application varied ever so little there would be a moment set up tending to rotate the body about the center of gravity.

If a piece of paper or other material is cut into any shape and suspended by a point and a straight line drawn across in the direction of the suspending line it will pass through the center

of gravity. If it is then suspended by another point and a line drawn as before the two lines will intersect in the center ot gravity.

What is called the center of gravity is really the center of mass or center of area. At the same time all centers of mass are not strictly centers of gravity.

The center of gravity of a straight line is the middle point. Of a parallelogram the intersection of lines connecting opposite corners. Of a circle the center. Of a triangle the intersection of the median lines. Fig. 28, (1), or = ⅔ the distance from the acute angle to the opposite side.

When a segment of a circle is cut off by a chord normal to the radius the center of gravity of the sector is $= \frac{2}{3} r \left(\frac{\text{Sin A}}{\text{A}} \right)$ where r is the radius of the circle and A is half the central angle of the sector in circular measure. The center of gravity of a parabola $= \frac{2}{5}$ b h, where b is the length of the chord normal to the axis and h is the distance from the chord to the vertex.

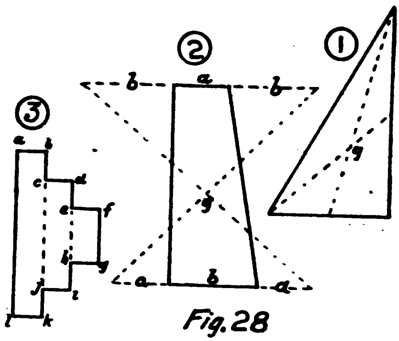


Fig. 28

Fig. 28 (2) shows a general method for determining the center of gravity of any regular figure. It requires no further explanation. In the same figure (3) shows a method of moments for calculating the position of the center of gravity of an irregular figure. Divide the area into any number of triangles, rectangles, etc., and ascertain the center of gravity of each and also the area. Take the distance of each center of gravity from the boundary

line (k l in this case) and multiply successively each area by its distance from the line. Add all the results. Divide this sum by the sum of the areas. The result will be the distance of the center of gravity from the line selected. Take next a line at the side of the figure and make the same calculations with respect to it. The result will be the distance of the center of gravity from that line. The intersection of the lines drawn through these positions parallel to the boundary lines selected, will give the position of the point called the center of gravity.

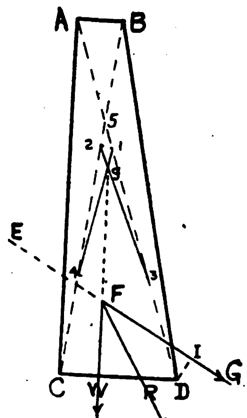


Fig. 29

Fig. 29 shows another method of calculating the position of the center of gravity in a retaining wall. Connect the opposite corners with lines A D and B C. Bisect them in 1 and 2. Lay off C 4 = B 5 and D 3 = A 5. Connect the points as shown and g is the center of gravity. The line E G represents the force tending to overturn the wall. The line F W represents the weight of the wall drawn through the center of gravity. F R is the resultant and D I the overturning moment. The resultant should pass through the middle third of the base to insure the stability of the wall. This will be taken up later.

The method of moments for finding the position of the center

of gravity is the neatest method in use. One example may be given of a retaining wall composed of two materials. The lower part of the wall is of a heavy stone and the upper part of brick, for example. The center of gravity of the whole wall will not be the center of gravity of the area. Divide the wall into two sections and find the center of area for each, which will be the center of gravity. Perpendicular lines through these two points will be parallel, but at a distance apart, enough to cause an appreciable moment.

The vertical distance forms a lever having at each end a weight corresponding to the weight of the section in which it terminates, for the weight of the wall is assumed as being concentrated in the center of gravity. By the theory of the lever the point on this vertical line at which these weights balance is the position of the center of gravity of the entire wall with respect to forces that might make it rotate from side to side.

The horizontal distance forms a lever having at each end a weight corresponding to the weight of the section through whose center of gravity the respective ends of this arm passes. Using again the principle of the lever the length of the arms causing the moments to balance can be found. Through the fulcrum on the vertical line draw a horizontal line and through the fulcrum on the horizontal arm draw a vertical line. The intersection will be the center of gravity of the complete section.

MOMENT OF RESISTANCE.

When a beam bends the upper fibers are compressed and the lower fibers are stretched. At some point between the top and bottom of the beam is a plane section termed the neutral axis, where the fibers undergo no change. This neutral axis passes through the center of gravity of the section. In a beam of rectangular cross section, composed of a material uniform throughout, the neutral axis is midway between the top and bottom.

If the lower part of the beam is composed of one material and the upper part of another the position of the neutral axis depends upon the readiness with which each material distorts under stress. This quality is known as the modulus of elasticity. It is important to remember this in the calculation of reinforced concrete beams.

In ascertaining the position of the center of gravity of the compound retaining wall an example is given of how the combination of different materials affects the position of the center of gravity. It is important to remember, therefore, that the neutral axis in beams and columns passes through the center of gravity of sections and that the center of gravity is not always the center of the whole area.

If a body is perfectly elastic it will lengthen or shorten in direct proportion to the strain. Suppose a bar to be stretched by a certain pull until it has been appreciably lengthened. Multiply the original length of the bar by the force and divide the product by the small extension caused by the force. The quotient is known as the "modulus of elasticity" and is generally indicated by the letter E.

Every material has a certain modulus of elasticity which may be low for stone, brick, concrete, etc., and high for iron and steel.

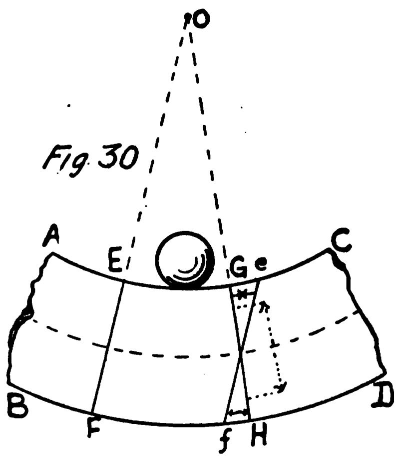


Fig. 30

To resist the bending moments already described a beam must possess a "moment of resistance," usually designated by the letter R. The moment of resistance is dependent upon several things usually not clearly expressed in elementary text books and hard to explain without the use of the calculus.

In Fig. 30 the figure A B C D represents a portion of a beam bent by a load applied at E. The beam is bent on a circle with a very large radius, the center of the circle being represented by O. The beam having bent has compressed on the upper side and extended on the lower side. To obtain the amount make the line f e parallel to E F and passing through a line midway between the top and bottom.

This line is the neutral axis and the distance G e shows the amount of the compression and the distance f H the amount of the extension. The alterations of length are proportional to the stresses, hence the stresses in any fibre are proportional to the distance of the fibre from the neutral axis.

This can be proven by calling s the unit fibre stress and s.y the stress at a distance y from the neutral axis. Imagine the area of the section of the beam to be composed of an infinite number of strips parallel to the neutral axis. The stress on one of these strips at a distance y from the neutral axis will be s.a.y where a represents the area of one of the strips.

The beam rests on the supports and the load is pressing it down. Consequently it can only move downward bodily or break by opening at the bottom. The tendency to open at the bottom must be resisted by an equal tendency at the top. The top forces can be called plus and the lower forces minus and each is represented by the expression s.a.y, where the period represents the multiplication sign.

If these forces do not balance, the section of the beam represented by the line G H will rotate around the point k. As this is impossible, it is evident the algebraic sum of the forces above and below the neutral axis, caused by the load, must be zero. That is, they must balance. As s.a.y represents a moment of force then the statement that all the moments around the point k balance, proves that the neutral axis must be in the middle of the beam, if the material is uniform.

In the section on centers of gravity the method of moments was explained. It was shown that the product of the whole area into the distance of its center of gravity from a certain point is equal to the sum of the products of the separate areas into their distances from the same point. Arguing from this we prove that

the neutral axis must pass through the center of gravity of the section of the beam, whether it is a simple or a compound beam.

Since the section on the line G H is not subjected to rotation because of the action of the opposite forces the statical moments acting in opposite directions must be equal.

The statical moment of the fibre resistance of some area distant y from the neutral axis is equal to the fibre stress into the distance y multiplied by the area a into the distance y., expressed.

s.y.a.y; or $s.a.y^2$

On the lower side of the neutral axis this will be minus and above plus. The algebraic sum will be zero. That is, the moments will balance.

The common factor s cannot be zero so is taken out and we have left $a.y^2$, which represents the sum of the products of each

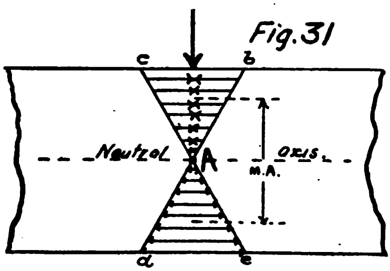


Fig. 31

infinitesimal strip multiplied by the square of its distance from the neutral axis. This expression is called the Moment of Inertia and is represented by the letter I.

The moment of inertia divided by the extreme distance of the most stressed fibre from the neutral axis is an expression designated by the letter S and called the section modulus. The section modulus multiplied by the fibre stress gives the moment of resistance. The moment of resistance is caused by the bending moment and must be at least equal to it or the beam will bend or break.

The section modulus is entirely dependent upon the shape of the beam section and independent of the material. The following example of the calculation of the section modulus of a rectangular beam may assist in making the subject clear.

It has been stated that the section modulus is equal to the moment of inertia divided by the extreme distance of the most stressed fiber from the neutral axis. Assuming a unit depth, d, then

$$S = \frac{1}{d/2}$$

The moment of inertia of a rectangular beam (a homogenous material being assumed so the neutral axis is in the middle) is

$$\frac{bd^3}{12}$$

and then

$$S = \frac{bd^3}{12} \times \frac{2}{d} = \frac{bd^2}{6}$$

The following description not involving the use of higher mathematics has been found useful:

Let R = moment of resistance in inch pounds.
b = breadth of beam in inches.
d = depth of beam in inches.
s = unit fiber stress.

In Fig. 31 the horizontal lines in the triangular spaces represent the forces, or fiber stresses, and the arrow points indicate the directions in which they act. As these forces increase towards the outside of the beam the area of the triangle may be considered as made up of the sum of these stresses and equal to $\frac{sd}{4}$

The centroid of the forces in each triangle is

$$2/3\left(\frac{d}{2}\right)$$

since all forces acting on a body act through the center of gravity and the center of gravity of a triangle is 2/3 the distance from the apex.

For the sake of the discussion (referring to the following page to prevent the grounding of wrong impressions), we will assume each triangle to be filled with a perfectly elastic substance, like rubber, fastened to the ends c A and b A, of the sections of the beam. When a load, represented by the arrow, comes on the beam the action of the resistance may be expressed thus:

$$R = \frac{b.s.d}{4} \times \frac{2d}{3} = \frac{s.b.d^2}{6}$$

As s represents the fiber stress it depends upon the material, so is not a necessary part of the expression.

The expression $\frac{2d}{3}$ is the sum of the distances from the neutral axis of the two triangles and is the moment arm.

The point k was unfortunately omitted in Fig. 30. It is supposed

to be midway between G and H where the dotted line is drawn. The dotted line parallel with G H and also shown on Fig. 31, where it is marked M A, requires explanation.

This line represents the moment arm of the resisting forces in the beam. In a number of reinforced concrete theories put forth, the moments of the concrete and in the steel are balanced around the neutral axis. That is, the fibre stress is multiplied by an arm equal to the distance from the neutral axis to the center of gravity of the section. Upon such an hypothesis the action is thought to be like a pair of scissors having a joint on the neutral axis.

As the weight is applied from the outside the action is represented in Fig. 30. This being the case the triangle that stretches may be represented by one having a height equal to the depth of the beam and a width at the bottom equal to d e (Fig. 31). The triangle that compresses has a height equal to the depth of the beam and a width equal to c b (Fig. 31). These two triangles are superimposed and when the forces that balance are struck out the form of strains left is like that shown in Fig. 31. In other words, the neutral axis is not a fulcrum around which opposing actions work, but is merely the point where two opposing forces balance and therefore equate to zero. The moment arm is the distance between the points where the force in each half of the beam is concentrated.

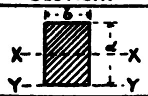
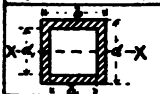
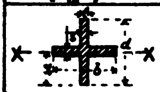
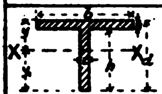
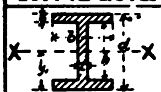
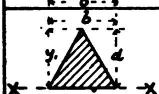
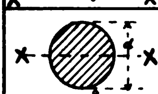
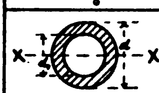
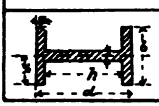
As the section modulus is a guide to the strength of a beam and is constant for all conditions of loads, independent of the spans, a table of S once calculated is good for all time. It does not vary in proportion to weight, so frequently the lightest beam having the proper value of S is the best to use for the sake of economy.

Let M equal the bending moment in inch-pounds and S equal the section modulus in inch units. Let s equal the allowable fibre stress.

$$\text{Then } M = Ss = R, \quad \text{and} \quad S = \frac{M}{s}.$$

Having shown by the calculation of the section modulus of a rectangular beam how the shape is all that has to be considered, we may use any form by using the correct value of S. We may use any material by using the right value of s. We may use any system of loading and change it as we desire by substituting for M its proper

value in terms of length or span, and of the loads, either concentrated or distributed.

PROPERTIES OF USUAL SECTIONS.				
SECTION.	AREA.	I	S	$r=\sqrt{\frac{I}{Area}}$
	bd	Axis $XX=\frac{bd^3}{12}$ Axis $YY=\frac{bd^2}{3}$	$\frac{bd^2}{6}$ $\frac{bd^2}{3}$	$.289d$ $.577d$
	$bd-b_1d_1$	$\frac{bd^3-b_1d_1^3}{12}$	$\frac{bd^3-b_1d_1^3}{6d}$	$\sqrt{\frac{bd+b_1d_1}{12}}$
	$td+s(b-t)$	$\frac{td^3+s^3(b-t)}{12}$	$\frac{td^3+s^3(b-t)}{6d}$	$\sqrt{\frac{td^3+s^3(b-t)}{12[td+s(b-t)]}}$
	$bs+ht$	$\frac{ty_1^3+by^3-(b-t)(y-s)^3}{3}$	$\frac{I}{d-y}$	$\sqrt{\frac{ty_1^3+by^3-(b-t)(y-s)^3}{3(bs+ht)}}$
	$bd-h(b-t)$	$\frac{bd^3-h^3(b-t)}{12}$	$\frac{bd^3-h^3(b-t)}{6d}$	$\sqrt{\frac{bd^3-h^3(b-t)}{12[bd-h(b-t)]}}$
	$\frac{bd}{2}$	$\frac{bd^3}{36}$	$\frac{bd^2}{24}$	$\frac{d}{\sqrt{18}}$
	$\frac{bd}{2}$	$\frac{bd^3}{12}$	$\frac{bd^2}{12}$	$\frac{d}{\sqrt{6}}$
	$.7854d^2$	$.049d^2$	$.098d^3$	$\frac{d}{4}$
	$.7854(d^2-d_1^2)$	$.049(d^4-d_1^4)$	$.098\left(\frac{d^4-d_1^4}{d}\right)$	$\frac{\sqrt{d^2+d_1^2}}{4}$
	$bd-h(b-t)$	$\frac{2sb^3+ht^3}{12}$	$\frac{2sb^3+ht^3}{6b}$	$\sqrt{\frac{2sb^3+ht^3}{12[bd-h(b-t)]}}$

A few values of the moment of inertia and of the section modulus are here given for use in simple work. For other shapes the reader is referred to the hand books of the steel companies and many excellent books on design of structures. Godfrey's hand Book ($2.50) is good.

BEAM FORMULAS.

It has been shown that the greatest bending moment in inch-pounds equals the section modulus times the allowable fibre stress, and that the section modulus equals the bending moment in inch-pounds divided by the allowable fibre stress.

If the quantities are in foot pounds then the bending moment equals one-twelfth the section modulus multiplied by the allowable fibre stress and the section modulus equals the bending moment divided by the fibre stress multiplied by twelve.

After the foregoing explanations it is not necessary to give a number of rules and formulas, for anyone can deduce rules to apply to any shape of beam.

The tables of strength of materials here following will enable them to be applied to any materials. The modulus of elasticity has been referred to already and it is the basis of comparison between materials as the section modulus is between shapes.

The strengths here given are the ultimate strengths of the materials. For safe loads divide as follows: For wrought iron and steel divide by four; for cast iron, divide by four; for wood, by eight, and for stone by six.

The usual fibre stress (safe) used for hard steel is 16,000 pounds to the square inch in tension, and for soft steel from 10,000 to 12,500 pounds per square inch.

DEFLECTION OF BEAMS.

The elastic limit of a beam is sometimes confused with the modulus of elasticity. They are different factors, however.

All materials are to some extent elastic. They will return to their original form when the load is removed. Finally, however, a load may be applied which will permanently lower their modulus of elasticity. The material then has taken what is called a "set." It has reached its elastic limit, which is usually about six-tenths the ultimate strength.

All beams bend even when strong enough to carry the load placed on them. A limit, however, is placed on the bending, or deflection, and when a beam is not strained beyond the elastic limit the deflection in inches is as follows:

$$\text{Def.} = \frac{W \times L^3 \times c}{E \times I}$$

Where W = weight in pounds,
L = span in inches,
c = a constant,
E = modulus of elasticity, and
I = moment of inertia.

The following values of c are used:

Beam supported at both ends, loaded in center	0.021
Beam supported at both ends, uniformly loaded	0.013
Cantilever loaded at end	0.333
Cantilever uniformly loaded	0.125

In order not to crack plastering no beam should deflect more than one-fortieth of an inch per foot of span.

The modulus of elasticity of steel is from 29,000,000 to 31,000,000 pounds. For cast iron about 15,700,000 pounds. For wrought iron about 26,000,000 pounds. For oak and pine (average), 1,300,000 pounds. For concrete from 2,000,000 to 3,000,000 pounds.

COLUMNS.

Columns may be in one of three classes as shown in Fig. 32.

They may fail by bending or crushing, or both. The strength to prevent crushing depends upon the compressive strength of the material of which the column is made. The ability to stand without bending depends upon a factor called the "radius of gyration." The ability to stand without either crushing or bending depends upon the quality of the material and the design.

A short column is stiffer than a long one of the same material. The first class of columns is fixed at both ends and is the strongest, considering the section. The one that is fastened at one end and hinged at the other, or with a pin end, is not so strong. The weakest form is a column with two pin ends. When the fixed column

bends it has two points of contra flexure if both ends are fast or one point if only one end is fast.

Reinforced concrete columns must have the loading reduced when the length exceeds ten times the diameter. The length should never exceed fifteen times the diameter. The extreme of length, however, is generally governed by the size of the column, which increases rapidly with height and consequently takes up valuable floor space.

Wooden columns should follow the same general rule as reinforced concrete.

Steel and iron columns and struts need to be reduced for load after reaching a length of twenty times the least width and should never exceed fifty times the least width.

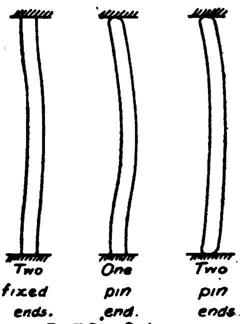


Fig. 32 Columns.

A beam begins to act as a column in the upper half as soon as loaded. Therefore after a wooden beam has a span of twelve times the least width it should be braced laterally and a steel or iron beam should be braced laterally for the same reason after the span exceeds twenty times the least width. Usually, however, they are braced at closer intervals.

RADIUS OF GYRATION.

An eminent engineer once said: "The radius of gyration is one of the most happy ideas of the fathers of engineering terminology. It is a first-class name, for it is not a radius and has nothing to do with gyration." The radius of gyration seems to have been a stumbling block to many writers. The writer has never

seen a definition that was capable of ready comprehension by the average man.

The term is one in common use, and is a factor used in the formulas for columns. It is to column formulas what the section modulus is to beam formulas. The radius of gyration of any section is the square root of the moment of inertia divided by the section area, and is written r.

Suppose a plank three inches thick and twelve inches wide is used as a column or strut. After a certain load has been placed on the end it begins to bend. To stiffen it a plate of steel half an inch thick is bolted to each of the sides. This makes a four-inch column of it. If the plates stiffen it sufficiently then the radius of gyration of that column is the distance from the neutral axis to the center of gravity (or area) of one of the added sections. In this case one and three-quarter inches.

Take another example. A three-inch solid cast iron column is bending under a load. It is taken down, but as no other material can be had it is recast into the shape of a hollow circular column. It then holds the load perfectly, although no new material has been added, because the radius of gyration has been increased.

Every section, except circles, has at least two radii of gyration. The least radius is the one used.

COLUMN FORMULAS.

For columns many formulas are used. The older formulas were extremely complicated, as they were generally deduced by reasoning upon a slight foundation knowledge of the properties of materials. Modern formulas are known as straight line formulas and are deduced from experiments on full size columns.

W = safe load in pounds.

l = length of column in inches.

r = least radius of gyration.

b = breadth in inches of least side, or diameter of round column.

p = working stress in lbs., per sq. in. of section.

a = area in square inches.

Steel Column—

$$W = p \times a$$

$$p = 17{,}100 - 57\left(\frac{l}{r}\right)$$

Wooden Column—

First Case—Length not more than twelve times the diameter or least breadth.

$W = a \times c.$

Where c equals one-tenth the strength in the tables of strength of materials.

Case II.—Length more than twelve times the diameter.

Yellow pine. $p = 850 - 8.5 \left(\frac{l}{b}\right)$

Oak and Norway fir. $p = 760 - 7.41 \left(\frac{l}{b}\right)$

White pine and spruce. $p = 630 - 6 \left(\frac{l}{b}\right)$

Hollow Round Cast Iron—

$p = 7625 - 40\left(\frac{l}{d}\right)$

Columns and walls and roof joints carry a load equal to that over an area measured half way to the next support in each direction.

As a general rule the compressive strength of wrought iron and steel is equal to the tensile strength.

Cast steel in compression is about 20 per cent stronger than in tension.

Cast iron is six times stronger in compression than in tension, a fact to be remembered in designing cast iron beams.

Wood is generally about two-thirds as strong in compression as it is in tension.

Stone and masonry generally ten times stronger in compression than in tension.

BUILDING LOADS.

The loads usually figured for buildings are as follows:

Roofs	40 lbs. per sq. ft.
Floors of dwellings and offices......	70 " " " "
" churches, theatres and ballrooms	125 " " " "
" warehouses	200 to 250 " " " "
" for heavy machinery..........	250 to 400 " " " "

BEARING PRESSURES.

Ordinary stone	180 lbs. per sq. in.
Good stone	300 " " " "
Brick in lime mortar	150 " " " "
Brick in cement mortar	200 " " " "

Concrete equal to best stone.
Rock in place will bear from 5 to 200 tons per sq. ft.
Dry clay from 2 to 6 tons per sq. ft.
Soft clay from 1 to 2 tons per sq. ft.
Gravel from 6 to 10 tons per sq. ft.
Sand from 2 to 6 tons per sq. ft.
Usual earth, etc., from 0.5 to 1 ton per sq. ft.

Feet of piers and masonry columns and walls should be stepped off at an angle of about sixty degrees with the horizontal to spread the load.

Piles generally carry from 10 to 15 tons each. Loads as great as forty tons have been used.

The Engineering News formula for the bearing load of piles is the best the author is acquainted with and is one in common use.

Let p = safe load in tons.
d = penetration in inches under last blow.
W = weight of ram in tons.
h = height of fall in feet.

then $p = \frac{2Wh}{d+1}$

This formula, and the fact is true for all pile driving formulas, should be used only when the pile is moving at each blow but with a perceptible lessening of movement. It is not good when the pile refuses to go any further.

A pile driven to "refusal" may be resting upon rock and thus be able to bear almost any load within the limits of the crushing strength of the wood, or it may have struck some small obstruction and be shattered as well. A good rule to follow is to stop driving when the pile stops moving, but do not continue driving after the above formula shows it is driven enough to carry the intended load. A pile is a column and the radius of gyration is not considered in computing the bearing power, for the necessary stiffness is furnished by the earth in which it is driven.

WOODEN BEAMS.

Table of safe quiescent loads for horizontal rectangular beams of white pine or spruce one inch broad, supported at both ends, the load being equally distributed over the span.

Span in feet.	Depth of Beam in Inches.										
	6	7	8	9	10	11	12	13	14	15	16
5	800	1090	1420	1800	2220	2690	3200	3750	4350	5000	5690
6	670	910	1180	1500	1850	2240	2670	3130	3630	4170	4740
7	570	780	1010	1290	1590	1920	2280	2680	3110	3570	4060
8	500	680	890	1120	1390	1680	2000	2350	2720	3130	3560
9	440	600	790	1000	1210	1490	1780	2090	2420	2780	3160
10	400	540	710	900	1110	1340	1600	1880	2180	2500	2840
11	360	490	650	820	1010	1220	1450	1710	1980	2270	2590
12	330	450	590	750	930	1120	1330	1560	1810	2080	2370
13	310	420	550	690	850	1030	1230	1440	1680	1920	2190
14	290	390	510	640	790	960	1140	1340	1560	1790	2030
15	270	360	470	600	740	900	1070	1250	1450	1670	1900
16	250	340	440	560	690	840	1000	1170	1360	1560	1780
17	230	320	420	530	650	790	940	1100	1280	1470	1670
18	220	300	400	500	620	750	890	1040	1210	1390	1580
19	210	290	380	470	590	710	840	990	1150	1320	1500
20	200	270	360	450	560	670	800	940	1090	1250	1420
21	190	260	340	430	530	640	760	890	1040	1190	1350
22	180	250	320	410	500	610	730	850	990	1140	1290
23	170	240	300	390	480	580	700	810	950	1090	1230
24	160	230	290	370	460	560	670	780	910	1040	1180
25	160	220	280	350	440	540	640	750	870	1000	1130
26	150	210	270	340	420	520	610	720	840	960	1090
27	150	200	260	330	400	500	590	690	810	920	1050
28	140	190	250	320	390	480	570	670	780	890	1010
29	140	190	250	310	380	460	550	650	750	860	980
30	130	180	240	300	370	450	530	630	730	830	950

This table has been calculated for extreme fiber strain of 1000 lbs. per square inch, being one-sixth the breaking strain, ordinary building timber of fair quality.

Oak and yellow pine will carry a load one-fourth greater.

When more accuracy is required, the weight of the beam itself must be deducted.

Care must be taken to let the beams rest for a sufficient distance on their supports to guard against crushing at the ends, especially in placing very heavy loads upon short but deep and strong beams.

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Safe load in pounds, uniformly distributed, for yellow pine girders supported at both ends. Allowable fiber strain 1,800 lbs. per sq. in. Factor of safety 4. For white or Norway pine, safe load should not exceed ⅞ of the amounts given.

Span in Feet	Size of Girder								
	8x10 7½x9½	8x12 7½x11½	8x14 7½x13½	8x16 7½x15½	10x12 9½x11½	10x14 9½x13½	10x16 9½x15½	10x18 9½x17½	10x20 9½x19½
10	13,537	19,837	27,337	36,037	25,127	34,627	45,647	58,187	72,247
12	11,281 9,284	16,531	22,781	30,031	20,939	28,856	38,039	48,489	60,206
14	9,669 6,816	14,169 12,114	19,526	25,741	17 948 15,343	24,734	32,605	41,562	51,605
16	8,461 5,220	12,274 9,270	17,086 14,990	22,524	15,705 11,742	21,642 18,990	28,529	36,367	45,153
18	7,521 4,124	11,021 7,328	15,187 11,842	20,021 17,924	13,959 9,282	19,237 15,000	25,360 22,705	32,326	40,137
20	6,768 3,338	9,918 5,970	13,668 9,592	18,018 14,520	12,564 7,562	17,313 12,150	22,824 18,392	29,094 26,467	36,124
22	6,153 2,760	9,017 4,906	12,246 7,926	16,380 12,000	11,421 6,213	15,739 10,041	20,750 15,200	26,450 22,880	32,840 31,572
24	5,640 2,318	8,265 4,118	11,390 6,660	15,015 10,080	10,470 5,216	14,428 8,436	19,020 12,768	24,245 18,383	30,103 25,368

Span in Feet	Size of Girder								
	12x14 11½x13½	12x16 11½x15½	12x18 11½x17½	12x20 11½x19½	14x16 13½x15½	14x18 13½x17½	14x20 13½x19½	16x18 15½x17½	16x20 15½x19½
10	41,917	55,257	70,437	87,457	64,867	82,687	102,667	94,937	117,877
12	34,930	46,048	58,698	72,880	54,056	68,956	85,556	79,114	98,233
14	29,941	39,469	50,312	62,470	46,334	59,062	73,334	67,812	84,198
16	26,198 22,988	34,536	44,024	54,660	40,542	51,680	64,166	59,336	73,673
18	23,287 18,158	30,698 27,845	39,132	48,587	36,037 32,265	45,937	56,960	52,743	65,487
20	20,958 14,708	27,630 22,264	35,220 32,040	43,728	32,434 26,136	41,344 37,611	46,677	47,469	58,938
22	19,053 12,155	25,117 18,400	32,017 26,485	39,753 36,550	29,485 21,600	37,585 31,090	46,667 42,905	43,153 35,697	53,580 49,262
24	17,465 10,212	23,024 15,456	29,350 22,253	36,440 30,710	27,028 18,144	34,478 26,123	42,778 36,050	39,557 29,993	49,116 41,390

Above heavy horizontal lines loads are calculated for both strength and stiffness. Below heavy horizontal lines the upper loads are for strength; the lower loads are for stiffness, with a deflection not exceeding $\frac{1}{30}$ in. per ft. span. The greater part of above table is taken from "Standard Wood Construction."

Safe Loads, in Tons of 2,000 lbs., for Square Wooden Posts.

Half seasoned white or common yellow pine.

C. Shaler Smith's Formula. Safe load in lbs. per square inch

$$= \frac{1250}{1+\left(\frac{l^2}{d^2}\times .004\right)}$$

l=Length of post in inches. d=Width of side in inches.

Height in feet.	Side of Square Post in Inches.								
	4	6	8	10	12	14	16	18	20
4	6.4	17.8	35.0	57.2	84.6	117.0	154.6	196.8	244.2
6	4.4	14.3	30.2	51.6	78.7	110.0	147.3	189.3	237.2
8	3.0	11.1	25.4	45.7	71.4	102.8	140.0	181.7	229.0
10	2.2	8.6	21.1	39.7	64.3	94.9	130.5	171.4	218.4
12	1.6	6.8	17.5	34.2	57.1	86.0	121.0	161.3	207.2
14	1.2	5.4	14.5	29.4	50.5	77.6	111.2	150.1	194.9
16	1.0	4.4	12.2	25.3	44.5	70.0	101.6	139.2	182.6
18	.8	3.6	10.2	21.8	39.2	62.7	92.7	128.2	170.2
20	.6	3.0	8.7	18.9	34.6	56.3	84.3	118.2	158.5
22	....	2.6	7.5	16.5	30.7	51.0	76.7	108.6	147.3
24	....	2.2	6.5	14.5	27.2	45.6	69.7	100.0	136.6
26	....	1.9	5.6	12.8	24.3	41.4	63.3	91.8	126.8
28	....	1.6	5.0	11.3	21.8	37.2	57.7	84.6	117.6
30	....	1.5	4.4	10.1	19.6	33.9	52.9	77.8	108.9
32	....	1.3	3.9	9.0	17.6	30.5	48.4	71.7	101.1
34	....	1.1	3.5	8.2	16.0	27.7	44.5	66.4	93.8
36	....	1.0	3.2	7.4	14.5	25.5	40.9	61.3	87.4
38	....	.9	2.9	6.7	13.3	23.5	37.5	56.8	81.2
40	....	.8	2.6	6.1	12.2	21.6	34.7	52.6	75.6
42	....	....	2.4	5.6	11.2	19.9	32.2	49.0	70.8
44	....	....	2.2	5.1	10.3	18.5	30.0	45.6	66.1
46	....	....	2.0	4.7	9.5	17.1	27.7	42.6	61.9
48	....	....	1.8	4.4	8.8	16.0	25.8	39.8	58.0
50	....	....	1.7	4.2	8.2	14.8	24.1	37.2	54.3
52	....	....	....	....	7.6	14.0	22.7	34.7	51.0
54	....	....	....	....	7.1	13.2	21.3	32.8	48.2
56	....	....	....	....	6.6	12.3	19.9	30.8	45.4
58	....	....	....	....	6.2	11.5	18.8	28.8	42.8
60	....	....	....	....	5.9	10.6	17.6	27.4	40.3

NOTE.—Oak posts will carry loads 15 per cent. greater than given above. Southern yellow pine will carry loads 40 per cent. greater than given above. The loads given in table are for posts in permanent structures. For posts in temporary structures add 25 per cent to the above loads.

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SINGLE I BEAM COLUMNS.

Safe Loads in Tons of 2,000 lbs.

Assumed strain per square in.=12,500 lbs. Reduced by Gordon's formulæ.

Depth of Beam.	Weight per foot.	Length in Feet.										
		10	12	14	16	18	20	22	24	26	28	30
24	100	148	135	124	113	102	93	84	76	70		
24	80	117	110	102	94	86	78	71	65	59	54	49
20	100	151	140	129	117	108	98	89	82	74	67	62
20	80	123	114	105	97	89	81	74	67	62	57	52
20	65	94	86	78	70	63	57	51	46	42		
15	100	149	138	126	115	105	95	86	79	71	62	
15	80	120	111	102	93	85	77	70	63	58	53	
15	60	87	80	72	66	59	53	48	43	39		
15	42	58	52	46	41	36	32	28				
12	55	74	66	59	52	46	41	36				
12	40	54	50	44	39	35	31	28				
12	31½	42	37	33	29	26	23	20				
10	40	49	43	37	32	28	25					
10	25	32	28	25	22	19	17					
9	35	41	35	30	26	23						
9	21	26	23	20	17	15	13					
8	25¼	28.2	24.5	20.8	17.8	15.6						
8	17¾	20.9	18	15.5	13.8	11.5						
7	20	21.2	17.9	15	12.8							
7	15	16.6	14.1	12	10.3							
6	17¼	17	15.1	11.8	10							
6	12¼	12.7	10.7	9	7.6							
5	14¾	13.5	11	9.1								
5	9¾	9.2	7.5	6.3								
4	10½	8.7	7									
4	7½	6.4	5.1									
3	7½	5.6	4.4									
3	5½	4.2	3.3									

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HOLLOW CYLINDRICAL CAST IRON COLUMNS.

Safe Loads, in Tons of 2,000 lbs.

Outside diam., inches.	Thickness of Metal.	Length of Columns, in Feet.									Sectional Area, inches.	Weight, lbs., of columns per foot of length.
		8	10	12	14	16	18	20	22	24		
6	½	26.2	23.0	20.1	17.5	15.2	13.2	11.5	.....	.....	8.6	26.95
6	¾	37.5	33.0	28.8	25.0	21.7	18.9	16.5	.....	.....	12.4	38.59
6	⅞	42.7	37.6	32.8	28.5	24.7	21.5	18.8	.....	.....	14.1	43.96
6	1	47.6	41.9	36.5	31.8	27.6	24.0	21.0	.....	.....	15.7	49.01
6	1⅛	52.2	46.0	40.1	34.8	30.2	26.3	23.0	.....	.....	17.2	53.76
7	¾	47.7	43.1	38.5	34.3	30.4	26.9	23.9	21.2	18.9	14.7	45.96
7	1	61.1	55.2	49.3	43.8	38.9	34.4	30.6	27.1	24.2	18.9	58.90
7	1⅛	67.2	60.8	54.3	48.3	42.8	37.9	33.7	29.9	26.7	20.8	64.77
8	¾	57.9	53.3	48.6	44.1	39.7	35.8	32.2	28.9	26.1	17.1	53.29
8	1	74.6	68.7	62.5	56.7	51.1	46.0	41.4	37.3	33.6	22.0	68.64
8	1¼	89.9	82.8	75.5	68.4	61.7	55.5	49.9	44.9	40.5	26.5	82.71
9	¾	68.1	63.6	58.9	54.2	49.6	45.2	41.2	37.5	34.1	19.4	60.65
9	1	88.0	82.3	76.2	70.0	64.1	58.4	53.2	48.4	44.1	25.1	78.40
9	1¼	106.6	99.6	92.2	84.8	77.6	70.8	64.4	58.7	53.4	30.4	94.94
9	1½	123.8	115.7	107.1	98.5	90.1	82.2	74.8	68.1	62.0	35.3	110.26
9	1¾	139.6	130.5	120.8	111.1	101.6	92.7	84.4	76.8	69.9	39.9	124.36
10	1	101.4	95.9	89.8	83.6	77.4	71.5	65.8	60.5	55.5	28.3	88.23
10	1¼	123.3	116.5	109.1	101.6	94.1	86.8	79.9	73.4	67.5	34.4	107.23
10	1½	143.7	135.8	127.3	118.5	109.7	101.2	93.2	85.6	78.7	40.1	124.99
10	1¾	162.7	153.8	144.1	134.1	124.2	114.6	105.5	97.0	89.1	45.4	141.65
11	1	114.8	109.4	103.5	97.3	91.0	84.8	80.2	73.1	67.7	31.4	98.03
11	1¼	139.9	133.3	126.1	118.6	110.9	103.3	97.8	89.4	82.5	38.3	119.46
11	1½	163.5	155.9	147.5	138.6	128.7	120.8	114.3	104.1	96.4	44.8	139.68
11	1¾	185.7	177.1	167.5	157.5	147.3	137.2	129.8	118.3	109.5	50.9	158.68
11	2	206.6	196.9	186.3	175.1	163.8	152.6	144.4	131.5	121.8	56.6	176.44
12	1	128.0	122.9	117.2	111.0	104.7	98.4	92.2	86.1	80.4	34.6	107.51
12	1¼	156.4	150.1	143.1	135.7	127.9	120.2	112.6	105.2	98.2	42.2	131.41
12	1½	183.3	175.9	167.7	159.0	149.9	140.9	132.0	123.3	115.1	49.5	154.10
12	1¾	208.7	200.4	191.0	181.1	170.7	160.4	150.3	140.5	131.1	56.4	175.53
12	2	232.7	223.4	213.0	201.9	190.4	178.9	167.6	156.6	146.1	62.8	195.75
13	1	141.2	136.3	130.7	124.7	118.5	112.1	105.8	99.5	93.5	37.7	117.53
13	1¼	172.8	166.8	160.0	152.7	145.0	137.2	129.4	121.8	114.4	46.1	143.86
13	1½	203.0	195.9	187.9	179.3	170.3	161.1	152.0	143.1	134.3	54.2	168.98
13	1¾	231.6	223.6	214.5	204.7	194.4	183.9	173.5	163.3	153.3	61.9	192.88
13	2	258.9	249.9	239.7	228.7	217.3	205.5	193.9	182.5	171.3	69.1	215.56
14	1	154.3	149.6	144.3	138.5	132.3	125.9	119.5	113.1	106.8	40.8	127.60
14	1¼	189.2	183.4	176.9	169.7	162.2	154.4	146.5	138.6	131.0	50.1	156.31
14	1½	222.6	215.8	208.1	199.7	190.8	181.7	172.3	163.1	154.1	58.9	183.07
14	1¾	254.4	246.7	237.9	228.3	218.1	207.6	197.0	186.5	176.2	67.4	210.00
14	2	284.8	276.2	266.4	255.6	244.2	232.4	220.6	208.8	197.2	75.4	235.12
15	1	167.4	162.9	157.8	152.1	146.0	139.7	133.3	126.8	120.4	44.0	137.28
15	1¼	205.5	200.0	193.7	186.7	179.3	171.5	163.6	155.7	147.9	54.0	168.48
15	1½	242.1	235.7	228.2	220.0	211.2	202.1	192.8	183.5	174.2	63.6	198.74
15	1¾	277.2	269.8	261.3	251.9	241.9	231.4	220.7	210.1	199.5	72.9	227.45
15	2	310.8	302.5	293.0	282.5	271.2	259.5	247.5	235.5	223.6	81.7	254.90

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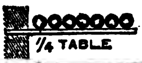
OOOOOOO FULL TABLE ; SAFE LOADS IN POUNDS STANDARD "I" BEAMS O ½TABLE

Span	3 Inch. 5½ lbs.	3 Inch. 6½ lbs.	3 Inch. 7½ lbs.	4 Inch. 7½ lbs.	4 Inch. 8½ lbs.	4 Inch. 9½ lbs.	4 Inch. 10½ lbs.	5 Inch. 9¾ lbs.	5 Inch. 12¼ lbs.	5 Inch. 14¾ lbs.	6 Inch. 12¼ lbs.	6 Inch. 14¾ lbs.	6 Inch. 17¼ lbs.
4 ft.	4410	4780	5186	7950	8470	9000	9520	12900	14520	16160	19370	21320	23280
5	3530	3830	4140	6360	6780	7200	7610	10320	11620	12930	15490	17050	18620
6	2940	3190	3450	5300	5650	6009	6350	8600	9680	10770	12910	14210	15520
7	2520	2730	2960	4540	4840	5140	5440	7370	8300	9230	11070	12180	13300
8	2210	2390	2590	3980	4240	4500	4760	6450	7260	8080	9680	10660	11640
9	1960	2130	2300	3530	3770	4000	4230	5730	6460	7180	8610	9470	10350
10	1770	1910	2070	3180	3390	3600	3810	5160	5810	6460	7750	8530	9310
11	1600	1740	1880	2890	3080	3270	3460	4690	5280	5880	7040	7750	8460
12	1470	1590	1730	2650	2820	3000	3170	4300	4840	5390	6460	7110	7760
13	1360	1470	1590	2450	2610	2770	2930	3970	4470	4970	5960	6560	7160
14	1260	1370	1480	2270	2420	2570	2720	3680	4150	4620	5530	6090	6650
15	1180	1280	1380	2120	2260	2400	2540	3440	3870	4310	5160	5680	6210
16	1100	1200	1290	1990	2120	2250	2380	3220	3630	4040	4840	5330	5820
17	1040	1130	1220	1870	1990	2120	2240	3030	3420	3800	4560	5020	5480
18	980	1060	1150	1770	1880	2006	2120	2870	3230	3590	4300	4740	5170
19	930	1010	1090	1670	1780	1890	2000	2720	3060	3460	4080	4490	4900
20	880	960	1040	1590	1690	1800	1900	2580	2900	3230	3870	4260	4660
21	840	910	990	1510	1610	1710	1810	2460	2770	3080	3690	4060	4430
22	....	....	....	....	....	....	....	2340	2640	2940	3520	3880	4230
23	....	....	....	....	....	....	....	2240	2530	2810	3370	3710	4050
24	....	....	....	....	....	....	....	2150	2420	2690	3230	3550	3880
25	....	....	....	....	....	....	....	2060	2320	2590	3100	3410	3720
26	....	....	....	....	....	....	....	1980	2230	2490	2980	3280	3580
27	....	....	....	....	....	....	....	1910	2150	2390	2870	3160	3450
28	....	....	....	....	....	....	....	....	....	....	2770	3050	3330
29	....	....	....	....	....	....	....	....	....	....	2670	2940	3210

STANDARD "I" BEAMS

Span	7 Inch. 15 lbs.	7 Inch. 17½ lbs.	7 Inch. 20 lbs.	8 Inch. 17¾ lbs.	8 Inch. 20¼ lbs.	8 Inch. 22¾ lbs.	8 Inch. 25¼ lbs.	9 Inch. 21 lbs.	9 Inch. 25 lbs.	9 Inch. 30 lbs.	9 Inch. 35 lbs.
4 ft.	27600	29850	32140	37920	40130	42740	45360	.....	.....	.....	.....
5	22080	23880	25710	30330	32100	34190	36290	.....	.....	.....	.....
6	18400	19900	21430	25280	26750	28500	30240	.....	.....	.....	.....
7	15770	17060	18370	21670	22930	24420	25920	.....	.....	.....	.....
8	13800	14930	16070	18960	20060	21370	22680	25160	27240	30180	33120
9	12270	13270	14280	16850	17830	19000	20160	22370	24210	26830	29440
10	11040	11940	12860	15170	16050	17100	18140	20130	21790	24150	26500
11	10040	10860	11690	13790	14590	15540	16490	18300	19810	21950	24090
12	9200	9950	10710	12640	13380	14250	15120	16770	18160	20120	22080
13	8490	9190	9890	11670	12350	13150	13960	15480	16760	18570	20380
14	7890	8530	9180	10830	11470	12210	12960	14380	15570	17250	18930
15	7360	7960	8570	10110	10700	11400	12100	13420	14530	16100	17670
16	6900	7460	8030	9408	10030	10690	11340	12580	13620	15090	16560
17	6490	7020	7560	8920	9440	10060	10670	11840	12820	14200	15590
18	6130	6630	7140	8430	8920	9500	10080	11180	12110	13410	14720
19	5810	6280	6770	7980	8450	9000	9500	10590	11470	12710	13950
20	5520	5970	6430	7580	8030	8550	9070	10064	10900	12070	13250
21	5260	5690	6120	7220	7640	8140	8640	9590	10380	11500	12620
22	5020	5430	5840	6890	7300	7770	8250	9150	9910	10980	12050
23	4800	5190	5590	6590	6980	7430	7890	8750	9480	10500	11520
24	4600	4980	5360	6320	6690	7120	7560	8390	9080	10060	11040
25	4420	4780	5140	6070	6420	6840	7260	8050	8720	9660	10600
26	4250	4590	4940	5830	6170	6580	6980	7740	8380	9290	10190
27	4090	4420	4760	5620	5940	6330	6720	7460	8070	8940	9810
28	3940	4260	4590	5420	5720	6110	6480	7190	7780	8620	9460
29	3810	4120	4430	5230	5580	5900	6260	6940	7510	8330	9140
30	....	....	....	....	....	....	....	6710	7260	8050	8880
31	....	....	....	....	....	....	....	9460	7030	7790	8550



SAFE LOADS IN POUNDS
STANDARD "I" BEAMS.

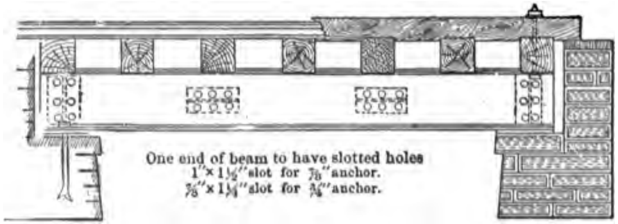
Span	10 Inch.				12 Inch.			15 Inch.				
	25 lbs.	30 lbs.	35 lbs.	40 lbs.	31½ lbs.	35 lbs.	40 lbs.	42 lbs.	45 lbs.	50 lbs.	55 lbs.	60 lbs.
10 ft.	26050	28620	31240	33850	38370	40580	43720	62830	64830	68750	72670	76600
11	23680	26020	28400	30780	34880	36890	39740	57120	58940	62500	66070	69630
12	21710	23850	26030	28210	31970	33820	36430	52360	54030	57290	60560	63830
13	20040	22020	24030	26040	29510	31220	33630	48330	49870	52890	55900	58920
14	18610	20450	22310	24180	27400	28990	31230	44880	46310	49110	51910	54710
15	17360	19080	20830	22570	25580	27050	29140	41880	43220	45840	48450	51060
16	16280	17890	19520	21160	23980	25360	27320	39270	40520	42970	45420	47870
17	15320	16840	18380	19910	22570	23870	25720	36960	38140	40440	42750	45060
18	14470	15900	17350	18810	21310	22540	24290	34900	36020	38200	40370	42550
19	13710	15070	16440	17820	20190	21360	23010	33070	34120	36190	38250	40310
20	13020	14310	15620	16930	19180	20290	21860	31410	32420	34380	36340	38300
21	12400	13630	14880	16120	18270	19320	20820	29920	30870	32740	34610	36470
22	11840	13010	14200	15390	17440	18450	19870	28560	29470	31250	33030	34820
23	11320	12450	13580	14720	16680	17640	19010	27320	28190	29890	31600	33300
24	10850	11930	13020	14110	15990	16910	18220	26180	27010	28650	30280	31910
25	10420	11450	12500	13540	15350	16230	17490	25130	25930	27500	29070	30640
26	10020	11010	12020	13020	14760	15610	16810	24160	24940	26440	27950	29460
27	9650	10600	11570	12540	14210	15030	16190	23270	24010	25460	26920	28370
28	9300	10220	11160	12090	13700	14490	15610	22440	23150	24550	25960	27360
29	8980	9870	10770	11670	13230	13990	15070	21660	22360	23710	25060	26410
30	8680	9540	10410	11280	12790	13530	14570	20940	21610	22920	24220	25530
31	8400	9230	10080	10920	12380	13090	14100	20270	20910	22180	23440	24710
32	8140	8950	9760	10580	11990	12680	13660	19630	20260	21490	22710	23940
33	7890	8670	9470	10260	11630	12300	13250	19040	19650	20830	22020	23210
34	....	....	....	....	11280	11940	12860	18480	19070	20220	21370	22530
35		....	....	....	10960	11590	12490	17950	18520	19640	20760	21880
36			....	....	10660	11270	12140	17450	18010	19100	20190	21280

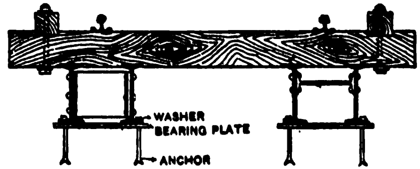
STANDARD "I" BEAMS.

Span	18 Inch.				20 Inch.			24 Inch.				
	55 lbs.	60 lbs.	65 lbs.	70 lbs.	65 lbs.	70 lbs.	75 lbs.	80 lbs.	85 lbs.	90 lbs.	95 lbs.	100 lbs.
10 ft.	94290	99770	104470	109180	124750	130110	135340	185530	192700	198970	205240	211205
11	85720	90700	94980	99250	113410	118280	123040	168660	175180	180880	186590	192290
12	78570	83140	87060	90980	103960	108430	112780	154610	160580	165810	171040	176270
13	72530	76740	80360	83980	95960	100090	104110	142720	148230	153050	157880	162710
14	67350	71260	74620	77990	89110	92940	96670	132520	137640	142120	146600	151080
15	62860	66510	69650	72790	83170	86740	90230	123690	128640	132650	136830	141010
16	58930	62360	65300	68240	77970	81320	84590	115960	120430	124360	128280	132200
17	55460	58650	61460	64220	73380	76540	79610	109140	113350	117040	120730	124420
18	52380	55430	58040	60660	69310	72280	75190	103070	107050	110540	114020	117510
19	49630	52510	54990	57460	65660	68480	71230	97650	101420	104720	108020	111330
20	47140	49880	52240	54590	62370	65060	67670	92770	96350	99480	102620	105760
21	44900	47510	49750	51990	59400	61960	64450	88350	91760	94750	97740	100720
22	42860	45350	47490	49630	56700	59140	61520	84330	87590	90440	93290	96140
23	40990	43380	45420	47470	54240	56570	58840	80670	83780	86510	89240	91960
24	39290	41570	43530	45490	51980	54210	56390	77330	80290	82900	85520	88130
25	37720	39910	41790	43670	49900	52040	54140	74210	77080	79590	82100	84610
26	36260	38370	40180	41990	47980	50040	52050	71360	74110	76530	78940	81350
27	34920	36950	38690	40440	46200	48190	50130	68720	71310	73690	76020	78340
28	33670	35630	37310	38990	44550	46470	48340	66260	68820	71060	73300	75540
29	32510	34400	36030	37650	43020	44870	46670	63980	66450	68610	70770	72940
30	31430	33260	34820	36390	41580	43370	45110	61840	64230	66320	68410	70510
31	30420	32180	33700	35220	40240	41970	43660	59850	62160	64180	66210	68230
32	29460	31200	32650	34120	38980	40660	42290	57980	60220	62180	64140	66100
33	28570	30230	31660	33080	37800	39430	41010	56220	58390	60290	62200	64100
34	27730	29340	30730	32110	36690	38270	39810	54570	56680	58520	60370	62210
35	26940	28510	29850	31190	35640	37170	38670	53010	55060	56850	58640	60430
36	26190	27710	29020	30330	34650	36140	37590	51540	53530	55270	57010	58760

Fibre stress 16,000 pounds per square inch and include weight of beam. Weight uniformly distributed.

I BEAM BRIDGES.





DOUBLE					TRIPLE				
SIZE	SEPARATORS	BEARING PLATES	WEDGE & ANCHORS.	WASHERS	SIZE	SEPARATORS	BEARING PLATES	WEDGE & ANCHORS.	WASHERS
24″	20″-I-65#1′-6″	18″ × ¾″ × 2′-8″	⅞″ × 12″	2½″ × 2½″ × ½″ × ¾″	24″	10″-I-25#1′-6″	18″ × ¾″ × 2′-8″	⅞″ × 12″	2½″ × 2½″ × ½″ × ¾″
20″	20″-I-65#1′-3″	12″ × ¾″ × 2′-6″	⅞″ × 12″	2½″ × 2½″ × ½″ × ¾″	20″	10″-I-25#1′-3″	12″ × ¾″ × 2′-6″	⅞″ × 12″	2½″ × 2½″ × ½″ × ¾″
15″	15″-I-42#0′-11″	12″ × ¾″ × 2′-0″	⅞″ × 12″	2½″ × 2½″ × ½″ × ¾″	15″	10″-I-25#0′-11″	12″ × ¾″ × 2′-6″	⅞″ × 12″	2½″ × 2½″ × ½″ × ¾″
12″	12″-I-31½#0′-9″	12″ × ¾″ × 1′-9″	¾″ × 10″	2″ × ½″ × ¾″ × 2½″					
10″	10″-I-25#0′-7″	12″ × ¾″ × 1′-6″	¾″ × 10″	2″ × ½″ × ¾″ × 2½″					

—JONES & LAUGHLIN HAND BOOK.

STRENGTH OF MATERIALS.

Ultimate Resistance to Tension.

In pounds per square inch.

Metals and Alloys.

	AVERAGE.
Aluminum Bronze,	
10 per cent. Al. and 90 per cent. Copper,	85000
1¼ " " 98¾ " "	28000
Brass, cast,	18000
" wire,	49000
Bronze or gun metal,	36000
Copper, cast,	19000
" sheet,	30000
" bolts,	36000
" wire, unannealed,	60000
Iron, cast, 13,400 to 29,000,	16500
" wrought, round or square bars of 1 to 2 inch diameter, double refined,	50000 to 54000
" wrought specimens ½ inch square, cut from large bars of double refined iron,	50000 to 53000
" wrought, double refined, in large bars of about 7 square inches section,	46000 to 47000
" wrought, universal mill plates, angles and other shapes,	48000 to 51000
" wrought plates over 36″ wide,	46000 to 50000

The modulus of elasticity of double refined bar iron is 25,000,000 to 27,000,000.

Iron wire,	70000 to 100000
" wire ropes,	90000
Lead, sheet,	3300

—JONES & LAUGHLIN HAND BOOK.

STRENGTH OF MATERIALS—Continued.

	AVERAGE.
Steel,	65000 to 120000
Tin, cast,	4600
Zinc,	7000 to 8000

Timber, Seasoned, and other Organic Fiber.

Taken largely from Trautwine's pocket book (edition of 1888.)

Ash, English,	17000
" American,	16000
Beech, "	15000 to 18000
Birch,	15000
Cedar of Lebanon,	11400
" American, red,	10300
Fir or Spruce,	10000
Hempen Ropes,	12000 to 16000
Hickory, American,	11000
Mahogany,	8000 to 21800
Oak, American white,	10000 to 18000
Oak, European,	10000 to 19800
Pine, American white, red and pitch, Memel, Riga,	10000
" " long leaf yellow,	12600 to 19200
Poplar,	7000
Silk fiber,	52000
Walnut, black,	16000

Stone, Natural and Artificial.

Brick and Cement	280 to 300
Glass,	9400
Slate,	9600 to 12800
Mortar, ordinary,	50

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STABILITY.

Fig. 33 shows how the stability of structures is computed. F is a force acting against the structure a b c d, with an arm f l. The line g h represents the weight of the structure drawn to any

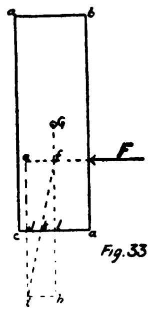


Fig. 33

scale and passing through the center of gravity g. The line f e is the force platted to the same scale in line with F. The line f i is the resultant.

To insure stability the moment of the distance c l multiplied by the weight of the section, should be greater than the moment of the force multiplied by the length f l. The latter is the overturning moment and the former the resisting moment.

If the point where the resultant touches the base is coincident with c then the structure is on the point of overturning. If it passes outside the base beyond c, the structure will overturn. In pracice the distance c k should not be less than one-third of c d. The resultant will then pass through the middle third. The effect of lessening the distance c k is to lessen the stability of the structure, to increase the danger of crushing the toe and to increase the pressure on the foundation. Occasionally piles have to be driven under the toes of such structures as retaining walls and dams, when economy in material demands that c k be sometimes less than one-third of c d.

It has been said that the force diagram can be drawn to any scale. The angle of the resultant is the thing sought. No matter what the length of the lines, the angle will be the same so long as

the lines are drawn in the right directions and of the right lengths. The scale can therefore be as large as the case seems to require. The upper corner is always on a vertical line drawn through the center of gravity of the structure and at a height equal to the point of application of the line of force.

This method of calculating stability is used for towers, tanks, bins, chimneys, dams, retaining walls, etc.

For retaining walls and dams the pressure is in the shape of a triangle at the back. The pressure at the top is zero and increases with depth. It acts at a point one-third up from the bottom, as all forces in a triangle act through the center of gravity, which occupies this position. A table of the pressure of water is given earlier in this chapter. A deviation from this statement as regards a triangular force against retaining walls will be mentioned later.

The pressure against towers, chimneys, etc., is caused by the wind. It is a distributed load acting on a cantilever beam and instead of being in the form of a triangle the force diagram is a parabola.

If the weight of the structure is insufficient to resist the overturning moment the additional weight required must be supplied by the foundation. If the ratio of base to height is very small the foundation must be spread. The upward reaction on the base is the action of a load on a cantilever beam in length equal to the distance from the edge of the structure to the edge of the foundation. Therefore the foundation is in the form of a truncated cone or pyramid. Sometimes for chimneys the depth of the foundation is equal to one-sixth the height of the chimney. The width of the foundation at the top is one-tenth larger than the base of the chimney. The width of the foundation at the bottom is one and one-half the top width. There is a tendency to pull the foundation over which is resisted by the weight. To enable this to be brought into play the structure must be anchored to the foundation and the force is converted into a pull.

The foregoing remarks about chimneys are true also of towers and tanks. Their strength is calculated by using the properties for hollow square or round beams, according to the shape the structure is given. If the structure is truncated the strength must be computed at the bottom of sections.

Wind pressure should be computed as being about 50 pounds

per square foot of surface as that is what a hurricane will frequently produce. The total pressure on a column will be the wind pressure multiplied by the radius of the column and its height. That is, the pressure on a round column is one-half the pressure on a flat surface having a width equal to the diameter of the round column. To find the total pressure when the wind is blowing against one of the diagonals of a square structure multiply the pressure against one of its sides by 0.707.

The pressure against a tower having a tank on top is due to a distributed load (the wind against the framework) and also to a concentrated load caused by the wind blowing against the surface of the tank. The distributed load on the frame work may be frequently neglected. There is a slight twisting strain set up when the pressure is against the corners of the tower. This is resisted by bracing the corners with short pieces.

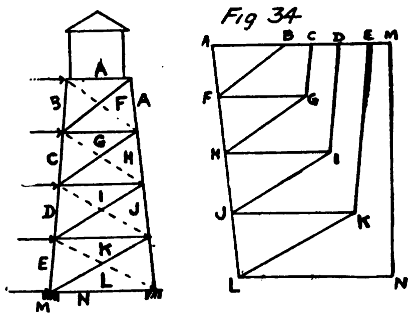


Fig. 34 represents a braced tower carrying a tank, and the stress diagram. The dotted lines represent cross braces that are not considered when drawing the stress diagram, for they are out of action when the wind is blowing from the direction in which we are now considering the force. The braces act alternately as ties and struts. A diagram for the wind from the opposite direction would be identical with the first, so only one is necessary, but the dotted counter braces would be considered and the solid ones omitted if the other diagram were drawn.

First letter the framework on the outside for each panel. From the point a, draw a horizontal line to represent the sum of the forces

at the joints and indicate the amount of each force by divisions in the line, properly marked. From the same point draw a line downward parallel with the batter post on the side opposite to which the wind is blowing.

From each joint mark, except the first, on the horizontal line draw a line parallel with the batter post on the opposite side of the tower. This will make the convergency toward the bottom in the stress diagram. From the first joint mark on the horizontal line draw a line parallel to the counterbrace to intersect the batter post line. From this intersection draw a horizontal line to intersect the batter line from the second joint mark. From this last intersection draw a line parallel with the next brace, etc., and continue until all have been connected.

The last line dropped from the end of the top horizontal line will be vertical and represents the upward pull on the anchorage. The horizontal line at the bottom, completing the diagram represents the compression in the bottom horizontal brace, or girt. This, however, will be much less because the posts are tied. The tower is also designed to carry the weight of the filled tank.

RETAINING WALLS.

A retaining wall may have both faces vertical or have one vertical and the other battered. If the batter is slight it is immaterial on which side it is placed. When appearance is considered it is usual to have the batter on the back and have the face plumb. This assists as well in making the wall safe, for the filling gets a better hold on the wall by friction.

If the batter is great the best plan is to place it in front so the excess of material will act as a stay. The weight of the earth on the sloping back assists somewhat in adding its weight to the wall to supply a resisting moment against overturning, but this effect is lost if the material becomes wet. Vauban's rule for converting a wall with two vertical faces, into one with a sloping face having the same resisting moment, is to so adjust the angle of the sloping face that the line will intersect the vertical face one-ninth of the height from the bottom. The procedure then is to mark a point one-ninth of the heighth from the bottom and put a line through it at any desired angle, even making the wall triangular in section if that

is wanted. By computing a wall with two straight vertical faces and afterward changing the front by this rule, a considerable saving in material can be effected.

Before discussing retaining wall theories the following rules in use generally by practical men are worth remembering.

Width at top one-tenth the total height above the surface of the ground.

Depth of footing at front edgè of wall five per cent of the height. Depth of footing at back of wall, seven per cent of the height.

Horizontal projection in front at toe of wall, below surface of ground, five per cent of height. This projection is often omitted.

Width (thickness) of wall at surface of ground as follows: For dry rubble, half the height; for good stone masonry, one-third the height plus one; that is, for a wall twenty-one feet the width will be one-third, equal to seven feet, plus one, making a total thickness of eight feet. For first-class stone or brick masonry, one-third the height. For first-class solid concrete, three-tenths the height.

Nearly all experiments on retaining walls have been with small models and with such materials as shot, peas, dry sand, etc. Experiments on large walls have not been enough in number to be of much value. Some experiments made within the last few years would seem to indicate that the pressure against a retaining wall for dry or moist earth should not be represented by a triangle but by a parabola. This would indicate that for low walls the pressure may be greater than a triangular force diagram gives and for high walls the pressure increases on a curve. As this curve gradually becomes straighter there may be a depth after which there is no increase in pressure, owing to some arching action in the filling. It has been suggested that a bounding curve for pressures might be drawn by starting with a diagonal line representing the pressure for saturated earth and another representing the pressure for dry earth. Draw a parabola tangent to the saturated earth line with a width equal to one-half the dry earth pressure at a depth of thirty feet. This curve would then represent the line of maximum pressure shown by the straight line m t in Fig. 35.

Experiments made on pressures in grain and sand bins of full size indicate that a parabolic line of pressure is correct for loose,

granular materials. Whether it applies, however, to earth is not fully known. Earth filling is often saturated, in which case it becomes a semi-fluid mass with an increased resultant pressure approaching a triangle in proportion as it loses cohesiveness.

In the table of weights of substances the weight of earth is given in different conditions. As the voids become filled with water the spaces formerly without weight take the weight of the water with which they fill. The angle of repose also lessens rapidly.

A number of theories have been proposed for the design of retaining walls but for plain gravity walls the empirical rules already given serve all purposes and agree closely with the best practice. Walls often have to stand pressures not foreseen, and sometimes forces that can not be calculated.

Today, however, a number of walls are built of reinforced concrete and in order to determine the dimensions some idea of pressures must be obtained. Theories of pressure are coming to the front in numbers and old ones are being revamped. In the end the idea of the line of maximum pressure being a parabola may obtain, but until it is proven the theory of Mosely, found in Trautwine's Civil Engineers' Pocket Book, and a score of other works, will be generally favored, as it is simple, and walls designed by it have proven safe. Other theories generally make thinner walls where gravity sections are used but make little difference in the case of retaining walls designed as slabs.

Fig. 35 is copied from Trautwine. The line m w represents the slope at which earth will stand. It is here assumed at one on one and one-half (generally termed 1½ to 1 slope) or an angle of 33° 41′ with the horizontal. The difference between that and 90° (the angle o m t) is 56° 18′. As earth will stand at the first slope mentioned there must be some slope steeper than that at which it will commence to fall toward the wall.

The line of maximum slope is taken at one-half the last angle or 28° 09′, represented by the line m t. This is known as the line of maximum pressure. The triangle o m t is the amount of earth that will press against a wall with a vertical back. For a wall with an inclined back the weight of the triangle c m o should be added to the weight of the wall.

The line y P represents in direction and length the weight of the earth backing. If the wall has a vertical back the line y P will

be horizontal. If the wall has a battered back it will be normal (at right angle) to the back of the wall. It is situated at a distance up of one-third the height of the wall as it represents a triangle of force through the center of gravity of which it passes. This triangle of force it is understood is widest at the bottom, for at the top of the wall the pressure is zero. It is therefore upside down as compared with the triangle of earth filling.

Referring again to Fig. 33 the overturning moment is the product of the force into the arm f l. In the retaining wall backed with earth there is a certain amount of friction between the back of the wall and the earth filling as the wall moves in overturning. This friction helps to prevent the wall overturning until it reaches

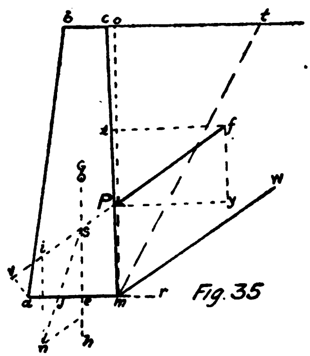


Fig. 35

a point where the earth falls behind the foot, provided the wall holds together. To find the effect this friction has we draw a parallelogram of forces y P f x. (Fig. 35.)

The angle y P f is 33° 41′ or the angle at which dry earth or sand will slide down masonry. Then y P represents the perpendicular pressure of the earth and x P the friction against the back. The line f P is the resultant of these two forces and this is what tends finally to make the wall overturn or slide or break or be forced into the soil.

Through the center of gravity of the wall draw the line g h. The resultant f P will pass through this line at s. Complete the parallelogram s i n o and draw the resultant s n. This passes

through the base at the point j which should be in the middle third. Trautwine says a j should not be less than one-fifth a m even with the best masonry and unyielding soil. While the middle third gives the best margin of safety a less distance can be used if too great crushing pressure is not thereby developed in the toe of the wall or in the soil under the toe.

When the back is offsetted or stepped instead of having a straight slope the pressure of the earth will be normal to a slant line drawn from the bottom to the top across the steps.

The moment tending to overturn the wall is the pressure f P multiplied by the length of the arm a v. The weight of the wall multiplied by the distance of its center of gravity from the point a is the resisting moment. While the arm a v in Fig. 35 is shorter than the arm f l in Fig. 33 the force f P, being inclined, is greater than the force y P.

For the purpose of calculating the pressure it is usual to consider a cubic foot of earth as weighing one hundred pounds. One cubic foot of masonry can be figured as weighing one hundred and fifty pounds. In obtaining the center of gravity the triangle of earth c m o must be taken into account, for its weight rests upon a projection at the foot of the wall equal to c o.

To assume a cross section of a wall having the proposed height use the empirical rules already given. Or calculate the overturning moment of the wedge of earth and draw a parallelogram of the right size to resist it, with the resultant passing through the toe. This can then be transformed by Vauban's rule into a section with an inclined face. It is usual to consider the section of earth as being a slice one foot thick and the same with the wall section.

If the wall is surcharged, that is, has a terrace on top, the procedure is the same. The line m t is produced to an intersection with the terrace slope, thus making the wedge heavier.

Fig. 36 shows a section of a reinforced concrete wall designed as a cantilever. Patents have been obtained on it so an extended description is hardly required here. The section is the same throughout the length. The reinforcing rods are all vertical and at the top and bottom are horizontal rods to prevent temperature cracks. The center of gravity is that of a compound section consisting of the wall and the earth filling resting on the slab at the bottom.

The diagonal reinforcement at the foot is to prevent the wall being broken at those points by the moments.

Such a wall can be made of timber in which case it is called a bulkhead. The face can be connected to the bottom slab by spikes and the front projection can be replaced by a brace. At the back the front slab will be tied to the bottom slab by a tie of wood or metal.

In fact many bulkheads and wooden retaining walls have been built by putting similar frames a number of feet apart and fastening heavy plank to the uprights by spiking them to the back or merely placing them at the back and counting on the pressure of the earth to hold them in place.

Such forms of walls are more economical of material than gravity walls, but wood is perishable. When built of stone or brick

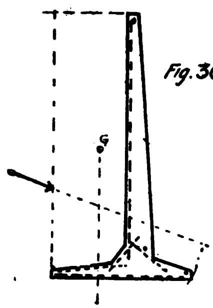


Fig. 36

the rear ties would be termed counterforts, but tear off readily. When placed in front they are termed buttresses, which are not always economical and have gradually assumed a place of ornament rather than utility.

Reinforced concrete, however, possesses all the desirable qualities of wood with the additional one of imperishability so walls of this modern material are coming rapidly into use. As generally designed they consist of a floor slab and a face slab like the letter L throughout the length of the wall. At regular intervals vertical ribs (counterforts) in the rear attach the two slabs so they will act as one section. While a number of such walls have been built, no study

has been published of the rib spacing in relation to height of wall in order to reduce cost. At present the spacing is arbitrarily settled by each designer.

In the following discussion the weight of the wall will be neglected. This adds to the factor of safety, adds practically nothing to the cost and simplifies the calculations. Methods of calculating strength of reinforced concrete beams will be taken up in pages following.

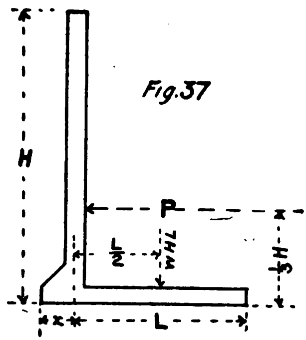


Fig. 37

Fig. 37 shows a section of wall assumed to be one foot long. There is a strip of filling one foot thick back of it tending to overturn it, and the overturning moment at the toe A must be resisted by the weight of the earth on the bottom slab. None of the earth tending to overturn the wall rests on the bottom slab and the parallelogram of earth on the slab is considered as the wall. The reinforced concrete wall in front merely retains the earth wall in place.

The vertical pressure therefore considered in the resisting moment is equal to w h l, where

w = weight of earth,

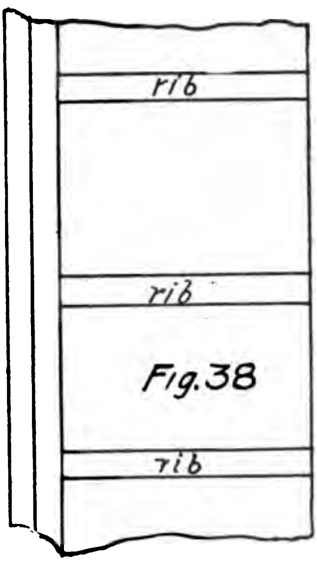
h = height of wall, and

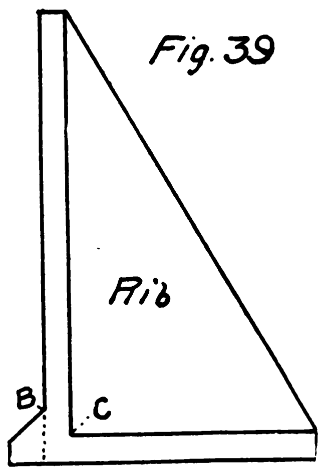
l = width of slab,

acting through center of gravity of the section h l. Assume x as equal to one-tenth the height and take moments about the toe for overturning, and resistance to overturning, as already shown for a gravity wall.

Figs. 38 and 39 show the ribs used to tie the face slab to the bottom slab.

The face slab is calculated as a slab made of beams lying on their sides and spanning between the ribs. The load on each beam is a distributed load between the ribs. The horizontal thrust against the wall has been found by Mosely's theory or any other. It is at the bottom but acting through a triangle is concentrated to cause an overturning moment, at one-third the height. The pressure of the earth against the bottom one foot beam of the face





slab to bend it, is equal to one-half the force multiplied by the height of the wall. This gives the load in pounds per foot. Multiply by the length in feet to get the total weight or load on the beam. Then use the formula $\frac{w\,l}{12}$, as the beam is a continuous one and multiply this by 12 to get inch pounds bending moment. A triangle can be drawn having this bending moment as the base and the height of the wall as the altitude. Horizontal lines drawn

through this triangle at other points give the bending moments of the other beams. Be careful to note the difference between the overturning moment of the wall as a whole and the bending moments of its component parts.

As the bending moments decrease toward the top smaller rods may be used or the rods can be spaced farther apart. This latter is best, for workmen are apt to make mistakes when rods differing in size are on the job.

The bottom slab consists of beams lying side by side and spanning between the ribs, being attached at the bottom. The greatest strain will occur if the whole structure tips forward and lifts the last beam on the rear edge off the ground. It then supports a distributed load one foot wide equal in height to the height of the earth over it and equal in length to the clear span between ribs. This beam being continuous the bending moment can be calculated as before. The bending moment decreases as a triangle toward the front face of the wall so the bars can be spaced wider as the face is approached.

The bottom slab is fastened at the front edge securely, for the wall tends to overturn at that edge. It is fastened to the rear end of the rib by the ties. When the wall tips as a whole the bottom slab acts as a beam with a span equal to the width of the slab from front to back. It has a distributed load tending to tear it from the bottom of the rib, at the middle. To prevent this short vertical bars attach the slab to the rib. The lengths of the bars are governed by their size and by the adhesive strength of the concrete.

The face slab has a tendency to tear off the front edge of the ribs and for the purpose of calculation the slab is considered as a vertical beam having a span equal to the height of the wall. To resist the stripping force short horizontal rods are set into the ribs through the slab. In both cases, however, these stripping forces are small. In the majority of walls the cohesion of the concrete will be amply sufficient without reinforcing ties.

The projection x has a width on top from the face to the outer end equal to x minus half the thickness of the face slab. This distance multiplied by the reaction under the face of the wall gives the bending moment tending to break the projection off at B. This is counteracted by putting bars across the base in the bottom

sufficient in number and size to resist the moment. Under the ribs the bars can be 1.5x long and half way between the ribs they can run across the base. They decrease in length as they approach the ribs. The thickness of the front end of the projection equals the thickness of the slab. At the wall it is twice as thick.

The top of the wall is tied to the rear end of the bottom slab by steel rods sufficiently strong. The concrete in the ribs protects these rods. In large walls where a material saving can be thus made in concrete, it is usual to have the rib open like a timber braced tie. In small walls the ribs are solid. The ties along the back edge of the rib are calculated by taking a moment at C tending to break the wall at that point by reason of the weight of earth on the floor slab attached to the rib, resisting the overturning moment. The weight of the earth is equal to that resting on an area equal to width of slab times span.

The foot of the wall and the bottom slab should be set well into the ground.

GRAIN AND SAND BINS.

Reference has been made to experiments made to determine the line of maximum pressure in bins containing grain or sand. The experiments were made by Mr. J. A. Jamieson and his paper appeared in Engineering News, March 10, 1904.

The editors of that paper gave the following formula (deduced by Mr. H. A. Janssen, of Hamburg), as having been proven by Mr. Jamieson's experiments to be correct.

V = vertical pressure of grain per square foot of depth below the surface of the grain.

w = weight of grain in lbs. per cubic foot.

f = coefficient of friction of grain against side wall.

k = ratio of lateral to vertical unit pressure.

R = ratio of area to perimeter of horizontal cross section of the bin.

e = the base of the Naperian system of logarithms.

$$V = \frac{R\,w}{f\,k}\left(1 - e^{\frac{-fk}{R}h}\right)$$

The formula may be simplified by reference to some practical considerations.

Wheat weighs 50 lbs. per cu. ft. Jamieson finds k for wheat closely 0.6, while friction coefficient f, for ordinary bin walls averages about 0.4. We may therefore take the product f k to be 0.25.

Further, for all square or round bins the ratio R is constant and equal to one-fourth the diameter. Using above values the formula becomes

$$V = 50d\left(1\cdot e^{\frac{-h}{d}}\right)$$

The term in the parenthesis approaches unity as the depth of grain increases. Limiting value of vertical pressure is therefore,

Vertical pressure in lbs. per sq. ft. = 50 times the diam. of bin in ft.

The term in parenthesis reaches a value of 0.9 when depth of grain equals 2.3 times the diameter of the bin. For all ordinary cases therefore, we may use the limiting maximum pressure directly.

The horizontal pressure is at all times 0.6 as great as the vertical pressure.

The formula means that the size of the bin determines the amount of pressure, whereas it was formerly believed the height alone had to be taken into consideration as in the case of fluid pressure. The vertical pressure being found by the formula, the horizontal or bursting pressure against the sides of the bin at that point is 0.6 the vertical pressure. The line of pressure is a curve, instead of a straight line as in the theory of the retaining wall already discussed. Part of the weight therefore goes into the walls and part goes to the floor.

The pressures given must be increased for other materials of greater weight. Using wheat weighing 50 lbs. per cu. ft. with an angle of repose of 28°, the coefficient of internal friction = 0.532.

TABLE OF COEFFICIENTS OF FRICTION OF WHEAT (JAMIESON.)

Wheat on wheat	0.532
Wheat on steel trough plate bin	0.468
Wheat on flat riveted plate and tie bars	0.375 to 0.4
Wheat on riveted cylinder	0.365 to 0.375
Wheat on cement concrete, rough or smooth	0.4 to 0.425
Wheat on tile or brick, rough or smooth	0.4 to 0.425
Wheat on cribbed wood	0.42 to 0.45

The ratio values for sand are practically the same but the weight per cubic foot is double.

BULKHEAD WALLS.

Many city engineers in places located on rivers, lakes or other bodies of water are called upon to design bulkhead walls.

For ordinary foreshore protection, a fill with a long gradual slope on the face, covered with large, carefully placed stones, is usual. For bulkhead walls, however, meaning thereby retaining walls with a front designed to permit vessels to come alongside, the engineer is not well provided with information, the literature being sparse and useful only to specialists.

Mr. S. W. Hoag, Jr., described in Engineering News, May 18, 1905, a method devised by him and Mr. D. C. Serber for calculating bulkhead walls in New York City. What follows is an abridgement of his article, illustrated with a copy of his drawing.

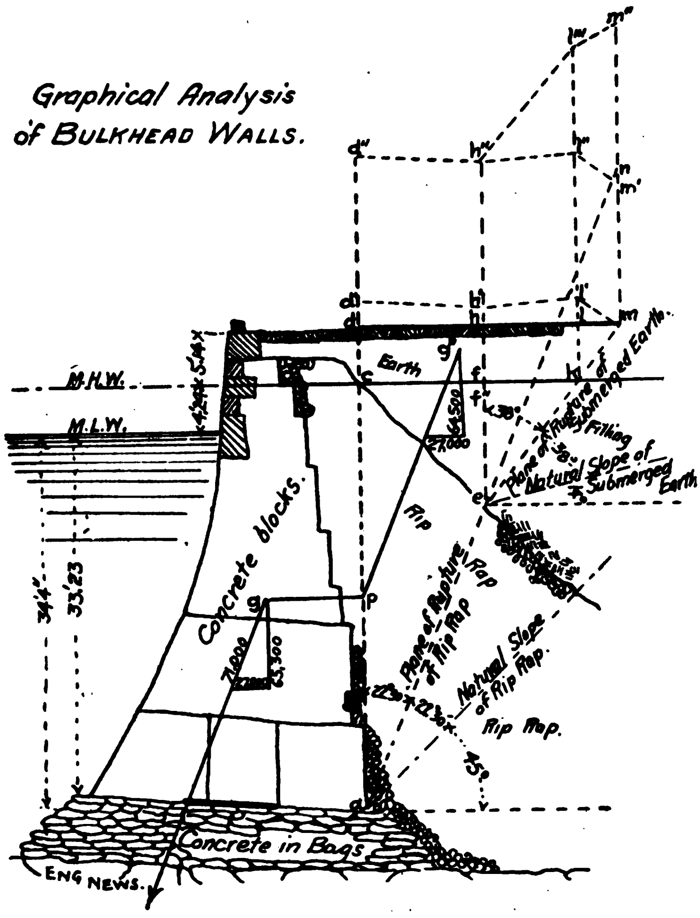
The subject is clouded with much uncertainty and experience is a most useful guide. The conditions given are an approximate cross section of submerged or of non-submerged wall, submerged sections and non-submerged sections of rip-rap filling and of earth filling and a surcharge of 1,000 lbs. per sq. ft. The analysis is conducted on the following assumptions:

Weight of rip-rap in air, 107 lbs. per cu. ft.; submerged rip-rap, 70 lbs., per cu. ft.; earth filling in air, 110 lbs. per cu. ft; submerged earth filling, 66 lbs. per cu. ft.; surcharge, 1,000 lbs. per sq. ft. of surface.

Erect a perpendicular a d. Lay off the prism of maximum thrust for rip-rap by the plane of rupture a e. Prolong a e to n. Denote the corresponding prism for the superimposed submerged earth filling by the plane e k, prolonged to m. Neglecting the change in plane of rupture for non-submerged earth filling, the limit of surcharge to be considered at the surface grade is contained between the intercepts d and m. Consider everything below mean high water as submerged and everything above mean high water as non-submerged.

First—Determine the weight of the submerged earth filling c e k, and replace it with a corresponding weight of submerged rip-rap. The top surface of the latter will then be c f′ k.

Second—Determine the weight of the non-submerged earth fill-



ing c d m k and replace it with a volume of submerged rip-rap of equal weight, and allow it to take its position upon the first

reduced volume of submerged rip-rap. This second volume will then be c d′ h′ l′ m k f′.

Third—Take the surcharge of 1,000 lbs. per sq. ft. and erect upon the top surface d′ h′ l′ m of this imaginary bank of submerged rip-rap, a prism of submerged rip-rap of such a volume as shall equal in weight the surcharge; the upper surface of this reduced volume will be d″ h″ l″ m′. The area a d″ h″ l″ m′ m e a represents in volume all of the back filling used in exerting pressure against the wall, reduced to one homogeneous material, namely, submerged rip-rap, weighing 70 lbs. per cu. ft.

To avoid the complication arising from a consideration of two planes of rupture a e and e m, consider alone the plane of rupture for rip-rap a n, for all the backfilling has been reduced to rip-rap. This is done by shifting the material represented by the area e n m to a new position, to form part of the prism limited by the plane a n, making h″ the new position for e, l″ l‴ the new position for k l′, and m′ m″ the new position for m n. The volume to be considered having the weights of submerged rip-rap, is now represented by the area a d″ h″ l‴ m″ n a.

The center of gravity of this area is at g′ and combining the weight of the mass through g′ with its horizontal component, the horizontal thrust on the back of the wall is 27,000 lbs., applied at the point p. Combining this thrust with the weight of the wall, represented by the vertical line 65,300 lbs., through its center of gravity, the resultant is 71,000 lbs. passing through the base at the point r.

In determining the center of gravity of the wall section it is, of course, necessary to consider the reduction in weight due to displacement below mean high water, of the two materials, concrete and granite, which enter into its construction, the weight of the non-submerged portion above mean high water, the weight of the submerged rip-rap on the steps in the rear of the wall, the weight of the superimposed volume of non-submerged rip-rap and of earth filling.

Older methods trace the pressures through the different materials, the several resultants finally after combination giving the total amount of thrust on the wall with its direction. The method just described is shorter, simpler and, practically, just as accurate.

ARCHES.

Arches today are generally built of reinforced concrete, but occasionally a brick or stone arch may be constructed.

The arch starts with a depth for the keystone and this depth is called the crown thickness. All formulas in general use are largely empirical, being averages of successful arch bridges put into convenient form by which other arches can be calculated. One used by the writer for several bridges (taken from an old English work) is as follows: Where d is the depth of keystone, or crown thickness, and r is the radius of arch at crown.

For a single arch $d = \sqrt{0.12\ r}$, and for a series of arches $d = \sqrt{0.17\ r}$.

The foregoing rules, however, are intended to apply more particularly to semi-circular arches under fairly high embankments. When the load is uniformly distributed the rise should be equal to about one-fourth the span, which gives a form approaching a parabola. The ring then can be of uniform thickness. Otherwise it must be thicker at the haunches.

All arches are supposed to have a curve of equilibrium located somewhere within the lines of the arch. The calculations are complicated and many empirical rules and methods are in use to enable arches to be designed, without going through the calculation of the equilibrium curve, of such proportions that this curve will lie in the middle third.

The ellipse is considered the most handsome curve in existence. The circle always has the appearance of an ellipse except when viewed from one point. The ellipse possesses certain properties of strength and equilibrium also which make it a good curve for an arch bridge. Therefore it is in common use. Ways of drawing an ellipse are given in many books. It is usual to construct an ellipse like a compound railroad curve, with several centers. But for arches having earth filling exceeding two or three times the thickness of the arch at the crown the semi-circular form is preferable. For arches having a very flat rise it is probably best to have a segmental arch of reinforced concrete.

The critical point in an arch is in the ring on each side of the center at a point equal to half the rise. This joint is on a radial line from the center from which that part of the underside of

the arch ring is struck. Fig. 40 shows a method proposed by Mr. Emile Low for drawing the arch ring in order to get the necessary additional thickness at the critical joint in the haunches. At the middle of the span draw a circle with a radius equal to the rise. From the same point describe an arc on each side with a radius equal to the half span. On this arc the point b will be on a horizontal line with the top of the arch ring. Draw the radius from the center to b. Drop a perpendicular from b and draw a horizontal line from a to intersect with it at c. Connect the points c and d with a straight line. Bisect it and produce it to an intersection with the perpendicular dropped from the center of the arch. This gives the radius with which to draw the arc c d on the underside. A

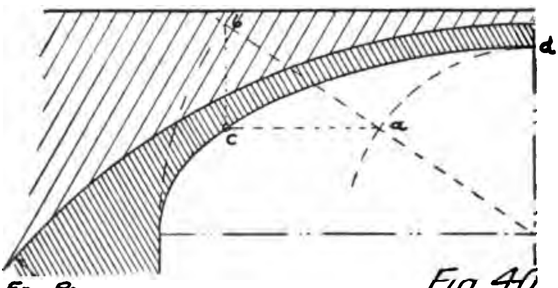


Fig. 40

radius from the same center but equal to the first plus the crown thickness is the radius used in striking the outer side of the arch. To get the radius for the sharper part of the underside from c to the bottom of the arch draw a line from the end of the span to c, bisect it and get the radius by the intersection with the radius of the larger circle.

This it will be seen gives the ring of uniform thickness to the point c. The depth of the arch ring for this construction is given by Mr. Low as follows:

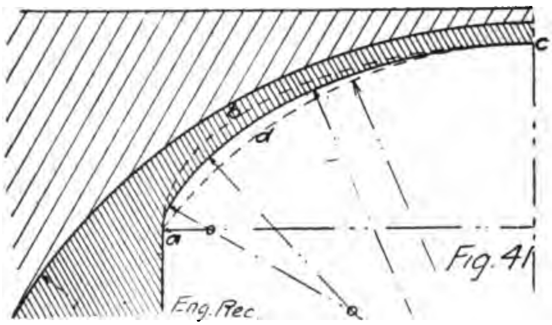
Let S = span of arch in feet.
R = rise of arch in feet.
H = depth of surcharge over arch in feet.
d = thickness of arch at crown in feet.

then $d = \frac{1}{8}\sqrt{(S - R)\,10 - 2H}$

Such an arch must be built of first-class brick or stone masonry. For reinforced concrete Mr. Daniel Luten (president of the National Bridge Company), states that this combination results in considerable economy over a segmental circular arch, but is too flat at the crown and too high at the haunches for an extremely light ring. such as might be used for reinforced concrete arches. He states, in Engineering Record, that it has been found that nearly all arches with elliptical intrados and thin arch rings will show slight cracks at the intrados crown.

A circular segment, on the contrary, will show cracks at the under surface at the haunches and will break away from the spandrels above the springings, showing that this curve is too flat at the haunches and too sharply curved at the crown for the earth loading.

He proposes the curve shown in Fig. 41, in which the inner curve is a mean between the ellipse and a segment of a circle having



the same rise and span, and the outer curve is a circle. In this figure the ellipse a b c is the same curve as the inner curve of Fig. 40; the circular segment a d c passes through the crown and the springing of the ellipse. The inner curve of the arch is then determined as a mean of these two curves by bisecting the vertical distances between. In order to facilitate laying it out, the curve is approximated by arcs of circles determined by trial after a sufficient number of points on the curve have been plotted.

The outer curve is a circle having its center on the center line of the arch and a radius equal to the radius of the intrados

at the crown plus two and one-half times the crown thickness. This relation between the radii of inner and outer curves results in an arch ring of a thickness varying approximately as the secant of the angle of inclination. Such a ring is believed to give better results for equilibrium than either an elliptical or a circular arch.

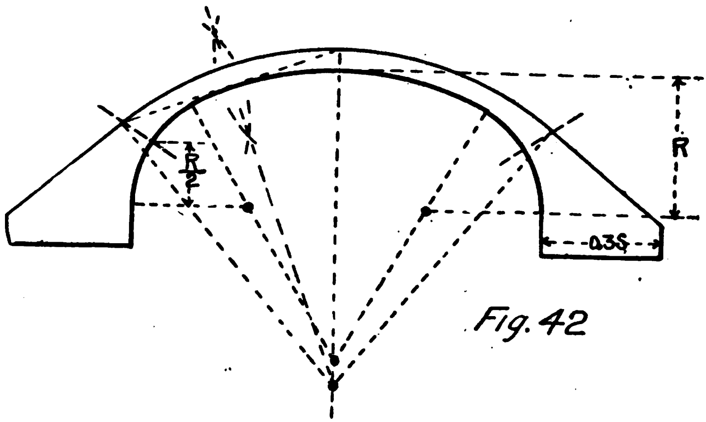


Fig. 42

Fig. 42 illustrates a method much in use for determining the thickness of the arch ring for arches of brick or stone masonry. The critical joint in each half span is at half the rise. Its thickness is determined as follows, where S is the clear span and R the rise, t is the thickness at the joint and d the crown thickness:

$$\frac{S}{R} = 3; \ t = 1.8 \text{ d.}$$

$$\frac{S}{R} = 4; \ t = 1.6 \text{ d.}$$

$$\frac{S}{R} = 5; \ t = 1.4 \text{ d.}$$

On squared paper the above values can be plotted and a line drawn so the thickness for other ratios can be obtained. For an elliptical arch the number of centers used in determining the inner curve is equal to the ratio. When the ratio exceeds 5 it is best to use reinforced concrete.

To determine the arch thickness throughout set out the inner curve and mark on it the length of the two critical radial joints.

Set off at the crown the thickness. Connect the upper end of this with the upper end of the joint on one side. Bisect this connecting line and produce the line bisecting it to a junction with the vertical line through the middle of the half span. This gives the radius of the outer circle of the arch ring. It stops at the critical joints, from which point the outer line is tangent to the outer curve.

If the height is increased by resting the arch upon vertical abutments the thickness of the abutment will be 0.3 span and at the rear end will rise until intersected by the outer arch line.

For the thickness of the crown of reinforced concrete bridges Mr. F. F. Weld gives the following in the Engineering Record:

C = thickness of arch ring in inches at crown.

S = clear span in feet.

L = live load per square foot uniformly distributed.

D = weight of fill over the crown per square foot.

$C = \sqrt{S} + 0.1S + 0.005L + 0.0025D.$

Example—To find thickness of arch at crown.

Span 60 feet.

Live load 200 lbs. per sq. ft., or 15 ton steam roller.

Fill over crown 2 feet thick.

$C = 7.7 + 6 + 1 + 0.55 = 15.2$ ins.

For railroad bridges add 50 per cent to the equivalent live load for impact.

Having determined C lay out arch. Rise is preferably 1/8 to 1-10 the span but will usually be governed by local conditions. Thickness of ring at critical joint should be 1¼ to 1½ C, depending upon curve of intrados.

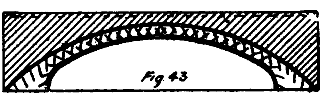
Steel reinforcement should be in two layers on account of reversal of stresses and made continuous over the entire span. Amount in each layer should be equal to 0.4 of one per cent (total 0.8%). There should be shear members rigidly connected to longitudinal rods and extending from one layer to another. Mr. Weld is engineer for a firm manufacturing a special reinforcing rod with such shear members. The shear members are necessary, however, at certain places on the arch and do no harm at all points as stated. With a well designed equilibrium arch the lower reinforcement can be dispensed with near the haunches, below the critical joint and the upper reinforcement can be omitted at crown,

provided plenty of shear members are placed on each side of the joint.

In this connection Mr. Luten says: "A concentrated load applied to the crown of such an arch as that of Fig. 41 will require reinforcement along the inner surface at the crown and along the outer surface at the haunches. By using one series of reinforcing members for both these regions and alternating the points of their crossing the arch ribs, the one system of rods can be made to reinforce the arch against all stresses. By distributing the points of crossing so that the rods will cross in the middle and thirds of the half arch, this reinforcement will provide also for all possible concentration of loads on the arch."

The difference in the two plans consists in the fact that Mr. Weld places reinforcement on both sides of his arch ring and has shear members the whole length. Mr. Luten reinforces his arch from a short distance on the outside of each critical joint on the bottom across to the same place on the other side. The rods are continuous from the outside end on top to where they cross the ring and go over on the underside. The top of the ring he does not reinforce between the places the outer rods cross to the bottom near the critical joint. He lightens his abutments by taking the rods down to the water level and crossing them under the bed in a concrete pavement, thus tying the abutments together.

Mr. Weld recommends that central piers should have a minimum of 1-12 the span and be battered for appearance and stability.



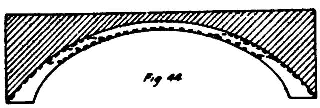


Fig. 43 shows an arch reinforced in a manner illustrating the ideas presented by Mr. Weld. Fig. 44 shows an arch reinforced in accordance with the ideas presented by Mr. Luten. Mr. Luten objects to the usual design of culverts with sides and tops figured as flat slabs, and makes a plea for the arch, this being more especially applicable to railroad culverts or culverts under embankments having railroad tracks on top.

He gives the following (Eng. News, May 24, 1906) for designing such culverts for spans up to 50 ft. and with not more than 10 ft. of fill over the crown.

$$\text{Crown thickness} = \frac{\text{Span}}{30} + \frac{1}{3}$$

Outer circle drawn with center 1-10 of span below center of inner circle.

Back of abutments tangent to outer circle and battered one in four.

Square inches of steel required to reinforce one edge of arch for 1 ft. in width $= \frac{H\ L}{400{,}000\ C}$

Where H is height of opening in feet, C is crown thickness in inches, and L is live load in pounds that can be concentrated on single track over half-span.

If the arch is reinforced near both edges (double reinforcement), the steel near the other edge must be added to the area given by the formula. If reinforced by a single series of rods, they should cross the arch rib at points one-third, one-half and two-thirds of the distance from springing to crown.

The arch, of course, carries the weight of the load, yet the observer only sees the underside of the arch. The road is carried on a straight line which is determined by the retaining walls (or spandrels) set on the outer edge of the arch. These walls are designed as regular retaining walls.

The abutments can be figured as already mentioned if the rise begins at the level of the ground or the surface of the water. If the arch rests upon abutment walls their thickness will be governed somewhat by the height of the embankment, for they will serve the double duty of retaining walls and arch abutments.

The point where the curve begins at the top of the abutment wall is termed the springing. The horizontal thrust of the arch at the top of the springing is equal to the total weight on the arch, including the weight of the arch, divided by 1.414. The vertical force at the springing, tending to aid the stability is equal to half the weight of the arch and load.

Calling H the height of the springing above the ground, the overturning moment due to the thrust on the arch $= \frac{w\ S^2}{8R} H$ where

w is the weight per lineal foot of arch and load, S is the span, and R is the rise. The resisting moment is $=\frac{WH}{2} + \frac{wSt}{2}$ where W is the weight of the abutment per cubic foot, and t is the thrust against the abutment at the springing. The moments can be compared with those acting against the abutment as a retaining wall and the one producing the heavier abutment will be used in the design. In adopting this method the support given the retaining wall by the arch can be taken into account, for the thrust of the fill will assist in counteracting the thrust of the arch.

CEMENT TESTING.

Every city engineer should have a cement testing outfit, but if the town cannot afford one he can make tests to satisfy him that the cement he is using is practically complying with the National standard specifications.

In the chapter on concrete simple acid tests are given to detect the admixture of raw material. When a cement is unusually light in color and does not wear well the acid test may show that considerable raw material was added to it after manufacture.

All things being equal, the finer a cement is ground the better it will be in concrete, or mortar. The first test, therefore, should be directed toward ascertaining the fineness. Obtain a scale that will weigh up to one pound by quarter ounces. Obtain from a reputable maker a 100 mesh sieve made of No. 40 wire, Stubbs' gauge, and examine it with a microscope to see that the interstices are uniform. Weigh out carefully three ounces of cement into the sieve. Holding the sieve in the right hand shake it rapidly but not violently at the rate of about twenty movements a minute, striking it gently against the ball of the left hand.

It will require about ten minutes' shaking, but if a few coins or telephone slugs are put in with the cement the operation will be hastened. When the cement seems to have stopped going through the sieve, pour the residue carefully on to the scales. As the standard specifications call for not less than 92 per cent to go through a 100-mesh sieve, this amounts to about, one-twelfth, or in three ounces to one-fourth of an ounce of residue. Make the test several times, or with six ounces instead of three occasionally.

The specific gravity test is beyond the reach of the greater number of engineers. The soundness test and time of setting are tests readily made. The specifications in the preceding chapter tell what to expect. For a Portland cement use about 20 per cent of water and conduct the operations in a room having a temperature close to 62 degrees F. Make a mortar of neat cement and water, mixing thoroughly for about five minutes under pressure, time to be estimated from moment of adding water and to be considered of importance.

Make on glass plates two cakes each about three inches in diameter, half an inch thick and drawn down to fine edges, and cover them with a damp cloth or place them in a tight box not exposed to currents of dry air. At the end of the time specified for initial set apply the needle one-twelfth of an inch in diameter, weighted to one-fourth of a pound to one of the cakes. If an indentation is made the cement passes the requirement for initial setting. If no indentation is made it is too quick setting. At the the end of the time specified for "final" set apply the needle one-twenty-fourth of an inch in diameter loaded to one pound. The cement cake should not be indented.

The needles mentioned can be made by anyone. Take two pieces of wire eight or nine inches long and file one end of each to the size mentioned. A ball of lead the required weight is then fastened on the wire. The wires are applied by holding them vertically between the fingers, letting the small end rest on the pat.

Expose the two cakes to air under a damp cloth for twenty-four hours. Place one of the cakes, still attached to its plate, in water for twenty-eight days; the other cake immerse in water at about 70° temperature supported on a rack above the bottom of the receptacle; raise the water gradually to the boiling point and maintain this temperature for six hours and then let the water, still containing the cake, cool. When making the boiling test it is important to keep the same depth of water over the cake. For the purpose haye another vessel beside the one containing the cake, full of water and add water from time to time to the testing vessel, to supply losses by evaporation. The added water being also boiling will not affect the test.

If the boiled cake shows evidences of cracking or distortion either reject the test or wait for the results of the twenty-eight-

day test of the cake in fresh water. The foregoing are the recommendations of the United States Army Engineers.

The tensile test is the one that is always mentioned in specifications and on which great reliance is placed. Briquettes are made of neat cement and about 20 per cent of water, and of 1 cement to 3 sand with about 12½ per cent of water. About one pound of cement is used and the mixture is thoroughly kneaded with the hands covered with rubber gloves. It is made into a ball and tossed from hand to hand for several minutes, after which it is pressed into the briquette molds firmly. Ramming it or tamping with a hammer is not always looked upon with favor, although these are customary methods for securing hard briquettes.

The lowest priced tensile testing machine costs about sixty dollars. The writer, in a previous book some years ago, mentioned the cross bending test as a fairly reliable substitute, and has made many tests with an ordinary water pail to apply the weight. He at first used bars one inch square and six inches long with a clear span over supports, of five inches. By experimenting considerably he finally made bars eleven inches long and one inch square resting on supports ten inches apart. A pail is hung over the middle of the bar, or beam, and the weight to be poured into the pail is practically about one-tenth the required tensile strength.

To make the beams use an iron frame such as printers use for forms. Have ten short pieces of steel or iron exactly one inch square and five strips of ¼ in. by 1 in. iron and set of printer's quoins. Set the iron blocks and strips in the frame so that there will be made five recesses each one inch square and eleven inches long. Put the cement mortar into these recesses and when set remove them to a box where they can rest without distortion or without being exposed to currents of dry air. They should be thus kept under a damp cloth for twenty-four hours and then be placed in water until needed for the seven-day and twenty-eight-day test. The writer breaks the five beams for each set of tests and takes the average as one-tenth of the required tensile strength. This gives an extremely close agreement with regulation tensile tests.

The sand should be either the standard sand recommended by the American Society or should be the standard crushed quartz. Still the very best sand used in the vicinity, carefully cleaned, will often do.

The cement should be brought on the site of the work at least ten days before it will be used in order to give time for a seven-day test.

In sampling cement, take every tenth barrel or every fortieth sack. Baking powder cans are excellent for taking samples to the testing laboratory. Carry them in a basket, or pail. About one pound should be taken from each sack.

Make a briquette or bar from each sample and then average the remainder for a test briquette representing the average of the lot.

Every book dealing with concrete contains considerable information on cement testing. The best book on the market today dealing with the subject is "Practical Cement Testing," by W. Purves Taylor ($3.00). Every engineer handling large quantities of cement should possess a copy. The subject of simple tests is fully treated in that work and the method of breaking beams in a cross-bending test is also fully gone ihto.

USEFUL LUTES AND CEMENTS.

Waterproof Compositions—Asphalt Fluid Coatings—Heat asphalt in a steam jacketed kettle and a mixture can be obtained with petroleum naphtha in which the part of asphalt not dissolved is held in suspension. Asphalt is entirely soluble in benzol or toluol, which are about the cheapest of all the constituents of asphalt. Tar and pitch are sometimes used in this connection, but tar contains water, light oils, and free carbon, and does not wear as well as refined asphalt; and pitch contains free carbon, which is sometimes objectionable when thinned out with a solvent. The asphalt alone is sometimes pervious to water, and this is improved by adding about one-fourth its weight of paraffin, and made better, if in addition a little boiled linseed oil is added also. For thicker compositions, where body is required, asbestos, stone powder, cement, etc., may be added as fillers.

Oil-Proof Compositions—For Small Leaks—Good glue or gelatine, 2 parts; glycerine, 1 part and water 7 parts. Apply warm and it stiffens quickly on cooling. Another very useful composition is a stiff paste of molasses and flour. A stiff paste of glycerin and litharge is oil-proof, acid-proof and water-proof. These form a chemical combination and set in a few minutes. By adding a little

water the paste will set more slowly. It is mixed as required. Plaster-of-Paris wetted by itself, or mixed with asbestos, straw, hair, etc., is useful. A solution of silicate of soda made into a stiff paste with carbonate of lime, gets hard in six to eight hours.

Acid-Proof Compositions—The asphalt compositions already mentioned, compositions of melted sulphur with fillers of stone powder, cement, etc., also the following which withstands hydrochloric acid vapors: Rosin, 1 part; sulphur, 1 part; fire-clay, 2 parts.

The lute composed of boiled linseed oil and fire-clay acts well with most acid vapors. Compositions of glycerine and litharge are useful, especially when made according to the Davis formula: Litharge, 80 pounds; red lead, 8 parts; "flock" asbestos, 10 parts, fed into a mixer, a little at a time, with small quantities of boiled oil (about six parts of oil being used).

A particularly useful cement for withstanding acid vapors, being also tough and elastic, is: Crude rubber, cut fine, 1 part; linseed oil, boiled, 4 parts; fire-clay, 6 parts. The rubber is dissolved in carbon disulphide to the consistency of molasses and then mixed with the oil.

The foregoing recipes were given by Samuel S. Sadtler, chemist, in a paper read on June 4, 1904, before the Philadelphia Engineers' Club.

Other useful formulas are found in Spon's "Dictionary of Workshop Receipts."

In a preceding section the writer has mentioned several methods of making water-tight joints in sewer pipes. In addition to the methods there described he has used a sulphur joint made of sulphur and sand. The sulphur is melted with the sand to a consistency where it will pour. A dam is made at the joint and the cement poured in like the lead in a water pipe. It cools very rapidly and if properly done is successful. The number of men having the skill and patience to do a good job this way, is small. Mr. Potter, the well known sanitary engineer is the one who first advocated this cement. Two or more lengths of sewer pipe are cemented together on the bank and lowered into place in the trench. As the cement practically makes one piece out of the several joined sections the total number of joints is reduced so they do not leak so freely. Care must be taken to have a bed the pipes will rest upon evenly.

Stone and Other Cements—For setting iron in stone the above

sulphur cement is good. From Mr. Sadtler the following recipe for stone cement is had: Zinc oxide, or magnesium oxide, 2 parts; zinc chloride or magnesium chloride, 1 part. Water to make a paste. Powdered stone is generally used as a diluent. An iron cement is made as follows: Iron filings, 40 parts; manganese dioxide or flowers of sulphur, 10 parts; salammoniac, 1 part; Portland cement, 20 to 40 parts; water to form a paste.

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